# A National Program of Research for

# SUGAR

Prepared by

A JOINT TASK FORCE OF THE
U. S. DEPARTMENT OF AGRICULTURE
AND THE STATE UNIVERSITIES
AND LAND GRANT COLLEGES

# FOREWORD

The United States Department of Agriculture and State Agricultural Experiment Stations are continuing comprehensive planning of research. This report is a part of this joint research planning and was prepared under recommendation 2 (page 204, paragraph 3) of the National Program of Research for Agriculture.

The task force which developed the report was requested to express their collective judgment as individual scientists and research administrators in regard to the research questions that need to be answered, the evaluation of present research efforts, and changes in research programs to meet present and future needs. The task force was asked to use the National Program of Research for Agriculture as a basis for their recommendation. However, in recognition of changing research needs it was anticipated that the task force recommendations might deviate from the specific plans of the National Program. These deviations are identified in the report along with appropriate reasons for change.

The report represents a valuable contribution to research plans for agriculture. It will be utilized by the Department and the State Agricultural Experiment Stations in developing their research programs. It should not be regarded as a request for the appropriation of funds or as a proposed rate at which funds will be requested to implement the research program.

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This report has been prepared in limited numbers. Persons having a special interest in the development of public research and related programs may request copies from the Research Program Development and Evaluation Staff, Room 318-E Administration Bldg., USDA, Washington, D.C. 20250.



June 1969

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# PREFACE

## Background

The long-range study, "A National Program of Research for Agriculture," conducted by a joint USDA-SAES Task Force, was published in October 1966. The second recommendation of the study called for a more systematic and continuing mechanism that would facilitate joint research program planning, evaluation, and coordination. The Agricultural Research Planning Commitee recommended the establishment of task forces to develop coordinated State-Federal plans for specified areas of research. Subsequently, thirty-two task forces were established of which this is one.

## Authority

The Joint Task Force on Sugar Crops was appointed jointly by G. L. Mehren, Assistant Secretary of Agriculture, and A. G. Hazen, Chairman of the Experiment Station Committee on Organization and Policy, and announced on March 5, 1968.

## Membership

USDA -- Thomas Theis, Chief, Tobacco and Sugar Crops Research Branch, Crops Research Division, Agricultural Research Service, Beltsville, Maryland - Co-chairman

Warren Bailey, Deputy Director, Farm Production Economics Division, Economic Research Service, Washington, D. C.

J. E. Clayton, Leader, Sugarcane Harvesting, Investigations & Farm Processing, Agricultural Engineering Research Division, ARS, Everglades Experiment Station, Belle Glade, Florida 33430

P. Luginbill, Assistant Chief, Grain & Forage Insects, Entomology Research Division, ARS, Beltsville, Maryland

V. H. McFarlane, Chief, Food Crops Laboratory, Southern Utilization Research & Development Division, P. O. Box 19687, 1100 Robt. E. Lee Boulevard, New Orleans, Louisiana 70119

R. J. Saville, Principal Agricultural Economist, Cooperative State Research Service, Washington, D. C.

C. W. Bennett, Collaborator, Agricultural Research Service, U. S. Agricultural Research Station, Salinas, California 93905

T. J. Henneberry, Chief, Vegetable and Specialty Crops Insects Research Branch, Beltsville, Maryland

E. V. Abbott, Collaborator, Agricultural Research Service, U. S. Sugarcane Field Station, Houma, Louisiana 70361

I. E. Stokes, Collaborator, Agricultural Research Service, Sugarcane and Sweet Sorghum Investigations, Beltsville, Maryland

SAES -- J. J. Mikell, Associate Director, Agricultural Experiment Station, Louisiana State University, Baton Rouge, Louisiana 70803 - Co-chairman

R. S. Loomis, Department of Agronomy, University of California, Davis, California 95616

Arturo Roque, Director, Agricultural Experiment Station, University of Puerto Rico, Rio Piedras, Puerto Rico 00928

W. R. Schmehl, Department of Agronomy, Colorado State University, Fort Collins, Colorado 80521

G. D. Sherman, Associate Director, Agricultural Experiment Station, University of Hawaii, Honolulu, Hawaii 96822

J. R. Orsenigo, Everglades Experiment Station, University of Florida, Belle Glade, Florida 33430

E. R. Stamper, Associate Professor, Department of Botany and Plant Pathology, Louisiana State University, Baton Rouge, Louisiana 70803

J. R. Campbell, Department of Agricultural Economics, Louisiana State University, Baton Rouge, Louisiana 70803

Advisors -- R. L. Cushing, Director, Experiment Station, Hawaiian Sugar Planters' Association, Honolulu, Hawaii 96822

W. Gibson, Head, Engineering Department, Experiment Station, Hawaiian Sugar Planters' Association, Honolulu, Hawaii 96822

J. H. Fischer, Secretary-Manager, Beet Sugar Development Foundation, P. O. Box 538, Fort Collins, Colorado 80522

M. G. Frakes, Agricultural Research Director, Michigan Sugar Company, Second National Bank Building, P. O. Box 1091, Saginaw, Michigan 48606

I. A. Hoff, President, U. S. Cane Sugar Refiners' Association, 1001 Connecticut Avenue, Washington, D. C. 20036

P. E. Jones, Secretary-Treasurer, U. S. Beet Sugar Association, 920 Tower Building, 14th & K Streets N. W., Washington, D. C. 20005

George Rush, Amalgamated Sugar Company, First Security Bank Building, P. O. Box 1520, Ogden, Utah 84420

E. F. Sullivan, The Great Western Sugar Company, P. O. Box 539, Longmont, Colorado 80501

E. H. Todd, Vice President, Research, United States Sugar Corporation, Clewiston, Florida 33440

Bion Tolman, General Agricultural Superintendent, Utah-Idaho Sugar Company, P. O. Box 2010, Salt Lake City, Utah 84110

Dudley Smith, Vice President, Association of Sugar Producers of Puerto Rico, 732 Shoreham Building, Washington, D. C. 20005

Staff Secretary: Max Hinds, Research Program Development and Evaluation Staff

## Assignment

This Task Force was asked to review and make recommendation with respect to research pertaining to sugar crops included in the "National Program of Research for Agriculture" under research problem areas 207, 208, 209, 307, 308, 309, 405, 406, 407, 408, 501, and 504.

## Participation of the USDA Sugar Crops Research Advisory Committee

The USDA Sugar Crops Research Advisory Committee and the Federal-State Research Task Force on Sugar Crops held a joint meeting March 19-21, 1969. A draft copy of the task force report was reviewed. Following this, the Advisory Comittee stated:

> The Sugar Crops Research Advisory Committee commends the Department of Agriculture and the State Agricultural Experiment Stations for the manner in which the long range study of agricultural research needs was organized and conducted. The Research Task Force made up of members from the U. S. Department of Agriculture, the State Agricultural Experiment Station, and the sugar industry has presented a thorough and complete picture of the research needs of sugar crops and the additional scientific manpower required to carry out the necessary research. The Committee supports and adopts the Research Task Force Report and recommends that it be implemented as rapidly as the necessary funds can be obtained.

The following persons are members of the Research Advisory Committee:

Franklin A. Beale, Central Mercedita Inc., Mercedita, Puerto Rico 00715
John B. Boy, Executive Vice President, U. S. Sugar Corporation, Clewiston, Florida
Gordon H. Miller, Sugarbeet Producer, Route 2, Box 110, Grandview, Washington
Owen S. Rice, President, California Beet Grower's Association, Santa Maria, California
Davis L. Sunderland, District Manager, Northern Ohio Sugar Company, Fremont, Ohio

# SUMMARY


## Introduction

Prior to completion of this report, the Task Force met jointly with the Sugar Crops Research Advisory Committee. The draft of this report was reviewed in detail as well as the usual Committee review of the current USDA program of research pertaining to sugar crops.

## The Sugar Industry:

- world production, 76,000,000 tons in 1968-69
- U. S. production, 7,000,000 tons
- average annual sugar consumption quite constant at 97 lbs per capita
- sugarcane, a perennial plant, is grown for domestic uses in Louisiana, Florida, Puerto Rico and the Hawaiian Islands
- sugarbeets, an annual crop, is grown in 20 states
- sweet sorghum grown as sirup crop in SE U. S.
- sugar industry is highly regulated
- number of farms producing sugar crops declined except in Florida
- yields have increased in most areas
- labor an important cost element
- few major changes have occurred in processing methods, however, commercial diffusors exist that extract 97% of the sugar from cane

## Research Perspective:

- in 1966, 137 SMY's engaged in sugar crops research, 52% SAES; 48% USDA

- of ten major research goals listed in the National Program of Research for Agriculture, parts of four are treated in this report: (1) Protection; (2) Production; (3) Product Development and Quality, and (4) Marketing

- sugar industry considers its grades, standards, and distribution of refined sugar well advanced and recommends very limited research

75% increase recommended for entire program - 104 SMY's

Protection: Goal II

- need non-chemical controls for insects as well as varieties resistant to insects

- need disease resistant varieties and other effective means of controlling or preventing diseases

- weed control an important problem in both cane and beets

80% increase recommended - 53 SMY's

Production: Goal III

- need for improved varieties with higher yield potential

- improved mechanization needed for sugarbeets for seedbed preparation, planting equipment and topping

- for recumbent sugarcane, there is urgent need for mechanized harvesting and cleaning

- systems analysis needed to improve management decisions for all sugar crops

- the efficiency of sugarbeet processing would be enhanced by improved processing qualities after long storage and for cane by improved quality retention after harvest

55% increase recommended - 34 SMY's

## Product Development and Quality: Goal IV

- loss of sugar in stored beets a serious problem
- more economical and more efficient extraction processes needed for cane
- need to develop new and improved methods for extraction of sugar
- need to increase the yield and purity of raw sugar from cane
- need to find more profitable utilization of bagasse from sugarcane and pulp from sugarbeets
- need to transform sucrose into high-value industrial products used in the chemical industry
- improved methods are needed for sampling, identifying, and measuring quality

214% increase recommended - 15 SMY's

## Marketing: Goal V

- sugar industry believes it has a highly efficient distribution system for refined sugar
- a modest research program needed in the public interest to keep abreast of changing technology and market conditions
- improved techniques and equipment for handling, storing, and transporting sugarbeets needed

50% increase recommended - 2 SMY's

# I. INTRODUCTION

The charge to the Sugar Crops Task Force was to envision the research needs and opportunities that would best advance the interest and welfare of the sugar industry in the decade ahead. To make meaningful recommendations about research for the sugar industry, a brief perspective of the industry's setting in the national economy was developed. Some of the important historical events are included.

## A. Importance and Nature of the Sugar Industry

1. Importance: The cash farm receipts value of sugar crops in the U. S. for 1967 was almost $386,000,000 -- representing slightly more than one percent of the cash receipts value of all agricultural commodities.

For a broader perspective -- sugar crops are produced throughout the world. The 1968-69 harvest-year production of centrifugal sugar, raw/value, is estimated at 76 million tons. The production by continents is:

| | |
|---|---|
| North America . . . . . . . . . . . . | 18.7 million tons |
| Europe . . . . . . . . . . . . . . . | 16.2 " " |
| Asia, other than USSR . . . . . . | 12.9 " " |
| U.S.S.R. . . . . . . . . . . . . . | 11.3 " " |
| South America . . . . . . . . . . | 9.1 " " |
| Africa . . . . . . . . . . . . . . | 4.9 " " |
| Oceania . . . . . . . . . . . . . . | 3.2 " " |
| Total | 76.3 million tons |

The U. S. produces 7 million tons of the North American total. Cuba is in second place with 6 million tons. The remainder comes from Central American countries and Carribean countries.

The average per capita consumption of sugar in the U. S. is about 97 pounds. More than half our supply is produced by domestic growers of sugarcane and sugarbeets -- the balance, almost all cane is imported.

Sugarcane is grown in Louisiana, Florida, Hawaii, and Puerto Rico. Sugarbeets are grown in 20 States ranked in the following order:

| | | |
|---|---|---|
| California | Montana | Arizona |
| Idaho | Wyoming | Maine |
| Colorado | Washington | Oregon |
| Minnesota | Texas | New Mexico |
| Michigan | Kansas | New York |
| North Dakota | Ohio | Iowa |
| Nebraska | Utah | |

The first three contribute half the nation's sugarbeet production.

2. Nature: The sugar industry of the United States is unique. There are two major sub-groups--the cane and beet sugar segments. The end product for both, refined sugar, is the same. Sugarcane is also used for sirup production as is sweet sorghum. There is considerable interest in sweet sorghum as a potential sugar crop.

The steps to produce sugar from the major crops differ. Sugar from cane requires a 3-step process as follows: 1) production of the crop, 2) manufacture of raw sugar, and 3) manufacture of refined sugar. The beet sugar industry on the other hand has 2 steps. The intermediate manufacture of raw sugar is deleted. These basic differences between the crops prevail in the domestic production areas.

Domestic sugar is produced under highly variable conditions. Forty-ton beet crops are produced in the semi-tropical California Imperial Valley. Soils are alkaline, the crop is irrigated, and temperatures may reach 120°F. Compare this to a 10-ton crop in the Red River Valley of the North Central States. Soils are prairie, a limited rainfall is the moisture source, and the frost-free period is short.

Cultural methods to produce the bulky, perishable sugar crops are drastically different. This is true in part because cane is a perennial plant frequently grown without rotation. Sugarbeets on the other hand are an annual, usually grown in a rotation. Even for a particular crop, the methods are diverse. For example, sugarcane in Hawaii is a 2-year crop that may be grown on rocky, steep hillsides. The soil is volcanic. Florida cane is a 12-month crop produced on flat terrain. The soil is reclaimed marsh that is almost completely organic.

Processing of sugar crops is equally diverse in terms of techniques, management, and ownership. There are several cooperatively owned raw sugar plants in the United States for processing sugarcane. Not so for sugarbeets. Beet factories extract the sugar by slicing and diffusion. Large mills are used to crush cane for extraction. Many sugarcane companies are vertically integrated in varying degrees. Some firms own facilities to produce the crop, and manufacture raw and refined sugar. There is very little such integration in the beet sugar industry. Beet companies are concerned with production, but their activity is largely confined to processing. Both industries compete vigorously in the

refined sugar market.

These concepts are changing as interlocking ownership of sugarbeet and sugarcane companies takes place. The incorporation of sugar companies into conglomerates with such diverse interests as food, oil, gas, and real estate will accelerate change of the traditional role of a sugar company.

The sugar industry is one of the most highly regulated agricultural industries in the United States. The Sugar Act of 1948 as amended, is the governing legislation. The sugar program is comprised of a multitude of techniques to deal with the maze of problems of producing, processing and marketing sugar. These include control of the sugar supply for the market, marketing quotas for domestic and foreign producers, marketing allotments for individual processors, acreage allotments for individual growers, minimum prices for purchased cane or beets, minimum wage rates for field workers, direct payments to producers with reductions for scale of operation; and an excise tax on all sugar manufactured in the United States.

The Sugar Act was last amended by the 89th Congress in 1965; unless extended, it will terminate December 31, 1971.

For additional information, see Appendix A.

## B. Historical Trends in the Sugar Industry

1. Trends in Production: Sugar production has increased in all domestic areas except Puerto Rico, where special conditions prevail. The increase has been variable due to an interplay of different factors. Quota provisions are one of these. The mainland cane area has been restricted by quotas. Puerto Rico and the beet area, on the other hand, have produced less sugar in recent years than their quotas permitted.

The availability of alternative agricultural opportunities is another important factor that affects sugar production. The diversified agriculture of New York State is a good example of competive crop effects. Producers have options of growing crops for the sugar, dairy, canning, milling industries and others. The competition for farmer interest and acreage is more intense than in areas where crops are more limited.

a. Number of Farms and Acreage
The number of sugarbeet and sugarcane farms has declined in all domestic sugar-producing regions except Florida. The decrease was greatest in Puerto Rico. During the

1958-62 period, the average number of farms was 14,971. It decreased to 10,663 during the 1963-67 period. A decrease of 29 percent. Compare this to Florida that had 36 farms during this first period and 160 during 1963-67 for an increase of 344 percent.

The changes in acreage correlate with the data on number of farms. The percent change for the same two periods are as follows: Louisiana +19, Florida +209, Hawaii +7, Puerto Rico -13, and the beet area +25.

b. Yields Per Acre
Yields of sugarcane and sugarbeets have increased in all regions, except Florida. The decrease in Florida is due to expansion of the industry to less productive soils. (See Appendix Table 1.)

c. Labor Requirements; Rates, Costs
Field labor is one of the most important costs to produce sugar. It is determined by the number of man-hours required and wage rates. The hours of labor to produce a ton of sugar have declined in all areas; the wage rates have increased. Wage rates have increased faster than the reduction of labor requirements in all areas except Hawaii. With this one exception, therefore, field labor costs per ton of sugar have increased. (See Appendix Table 2.)

2. Trends in Processing: There have been few major changes in conventional methods of manufacturing sugar. New concepts, however, have been developed as a result of research. Cane, for example, has always been milled by crushing. Today, commercial diffusors exist that extract as much as 97 percent of the sugar by a diffusion process. The principles of manufacturing liquid sugar by ion-exchange have been developed. Basic research on the organic non-sugar constituents has been essential to the improvement of the clarification process. Savings of a fraction of a cent per pound in processing are important to the industry.

3. Trends in Marketing and Consumption: Per capita consumption of sugar has been quite constant. During a period when the population increased nearly 8 percent, sugar consumption increased a little more than 7 percent. This occurred despite a diet-conscious nation and the exploitation of synthetic sweeteners. Sugar's share of the market for the major sweeteners--sugar, corn and noncaloric--declined from about 87 percent of the total in 1957 to 81 percent in 1965. Nonsugar sweeteners have become more important in food industries that make ice cream, soft drinks, and canned fruit. Further increases in the use of nonsugar sweeteners appear likely. In spite of this, the per capita

consumption of sugar has remained about the same. In other words, per capita consumption of all sweeteners as a group increased due to expanded consumption of nonsugar sweeteners.

The cost of sugar is rising; the amounts differ according to the user. Food processors, accounting for 70 percent of the refined sugar market, experienced a 14 percent rise in the wholesale price. This compares with a 5 percent increase in the wholesale price of food. The increase in the retail price of refined sugar, however, was practically the same as the increase of food prices. It amounted to 8 percent for both groups.

## C. Research Perspective and Comments

The 1966 inventory of agricultural research shown in Table 1, page 11 indicates that 137 scientist-man-years were devoted to research pertaining to sugar crops. Fifty-two percent of the research was conducted by the State Agricultural Experiment Stations and 48 percent by the United States Department of Agriculture. The Task Force recommended an increase in this effort to 241 SMY's, an increase of 75 percent, about evenly divided between cane and beets, Table 2, page 12.

Sugar research has helped growers, processors, and merchandisers provide consumers with a dependable supply of a pure food at a reasonable price. Technology has changed drastically since 1910-14 when the raw sugar price was 4.9 cents per pound. The benefits of research enabled the industry to absorb a steep rise in costs. Despite inflation since 1910, raw sugar sold for 7.5 cents per pound in 1968. This rise of 86 percent is much less than for other farm products.

A recent achievement typifies the benefits that have accrued to the sugarbeet grower. A serious fault of the sugarbeet was its multigerm nature. Several seeds were contained in a ball or aggregate. This required thinning by laborious, expensive handwork. A research breakthrough was exploited. Today the sugarbeet is monogerm. This results in a doubling of field labor efficiency.

Yield increases from improved varieties and cultural practices have contributed a tremendous gain in efficiency to the sugarcane grower. Examples are: C.P. 57-603 for Florida producing 47 percent more sugar per acre and L 69-96 for Louisiana growers.

A new sugar technology may develop utilizing sweet sorghum as a sugar source. Research to exploit the sugar potential of the crop was accelerated during World War II. A refining problem and disease

susceptibility were the major difficulties. High levels of resistance were incorporated into new varieties. Techniques were developed to rid the juice of starch and aconitic acid. The potential of sweet sorghum is being probed as a supplement crop to cane and beets. In combination, these crops may extend the processing season of factories thereby increasing efficiency.

Processing is an important step to produce sugar. A large investment is involved in complex equipment. A changing technology to meet new processing problems depends on research.

Research on by-products of processing has paid dividends. Beet pulp and molasses are combined to form a nutritious, pelletized animal feed. A food condiment is a marketable product. Basic research on fermentation has been the basis for production of uniformly high quality rum from molasses. A technique was devised for recovering aconitic acid from molasses. Uses have been developed for bagasse in some areas.

1. Future Agricultural Research Needs

In the National Program of Research for Agriculture, 10 goals were established to facilitate a systematic approach to determine future research needs. The goals are:

| | |
|---|---|
| I | Resource conservation and use |
| II | Protection of forests, crops and livestock |
| III | Efficient production of farm and forest products |
| IV | Product development and quality |
| V | Efficiency in the marketing system |
| VI | Expand export markets and assist developing countries |
| VII | Consumer health, nutrition and well being |
| VIII | Raise level of living of rural people |
| IX | Improve community services and environment |
| X | Basic research |

Of these goals, only parts of four were assigned for consideration by this Task Force. They are: II, III, IV, and V.

2. Future Sugar Crops Needs

a. Goal II, Protection of Crops: The objective of this goal would involve seeking basic information on insects, diseases, weeds, and environmental hazards that cause losses in field crops and to develop effective economic means for their control or elimination.

This objective was broken down further into 14 research problem areas of which three were applicable to sugar crops. The three are:

RPA 207, Control of Insect Pests; RPA 208, Control of Diseases; and RPA 209, Control of Weeds and Other Hazards.

The hazards of producing sugar crops are ever present. Insects, diseases, and weeds comprise a plastic biological system. It molds and changes to meet new production methods. The tools to meet these hazards are too limited and too specific. They will remain so until we are more knowledgeable about each predacious agent.

The limited information about infectious pests keeps the sugar industry constantly in a risky defensive position. Control of the sugarcane borer in Louisiana with Endrin, for example, was economic and effective, until the borer became resistant and Endrin could no longer be used. Also, control of curly top with disease resistant sugarbeets saved the industry in the Western States. The relief, however, is short-lived; the pathogen mutated. The constantly changing array of herbicides has not yet provided mastery of the weed control problem. We depend on relatively unknown, undependable weed-herbicide-crop-soil-climate interactions for control.

b. Goal III, Efficient Production: The objective of this goal is the production of an adequate supply of farm and forest products with decreasing production costs.

The objective was further broken down into 16 research problem areas of which three were applicable to sugar crops: RPA 307, Biological Efficiency of Field Crops; RPA 308, Mechanization of Production of Field Crops; and RPA 309, Systems Analysis in Production of Field Crops.

In addition, Goal IV, "Product Development and Quality" contains a research problem area 405, "Production fo Field Crops with Improved Consumer Acceptability " which is applicable to sugar crops.

The sugar industry of tomorrow will demand new, more efficient, foolproof methods to control production hazards. They will be provided as flexible, biological-chemical, production systems are devised. We should envision techniques that can be programmed years in advance. These systems will anticipate and counteract potential production hazards. We should no longer be forced to move from "emergency to emergency".

The greatest gains to the sugar industry have been achieved by research on production problems. Despite this, the full potential is yet to be tapped. In some respects, the reservoir of basic information which can be applied to production problems is exhausted. Attention to the need for new information must not diminish.

The ultimate benefit of all crop research is to provide more efficient means of providing the nation's food, feed, and fiber needs while at the same time improving the quality of our physical and social environments. Research makes it possible to achieve this end by finding out how to increase yields and to improve efficiency. There are two broad routes to higher yields and greater efficiency to be found in this research area: (1) improving varieties, and (2) manipulating the plant and its environment.

Great strides have already been made in increasing yields of sugar through breeding improved varieties. Additional benefits can be attained by developing new and more rapid methods of breeding. Specifically, there should be research leading to sugar varieties with greater adaptability to prescribed environments along with greater resistance to diseases, insects, and other pests.

The development of varieties with the genetic potential for high yield, must be coupled closely with studies on the manipulation of the plant and its immediate environment to optimize all cultural practices. For too long we have ignored the basic principle that the genetic material can be altered to match improved environments such as high nitrogen, just as well as the environment can be modified to meet the needs of a new variety. The research needed to make this possible should be directed toward several goals as follows: protecting against loss of yield due to insufficient or excessive amounts of nutrients or other elements; improving efficiency in utilization of all resources, including land, capital, equipment, and manpower; determining how to assign varieties precisely to a specific environment by modifying cultural practices; and using chemical control of plant characteristics to produce desired growth patterns as, for example, induced tillering of sugarcane and inhibition of beet growth to favor sugar accumulation.

Mechanization research has the objective of developing machine principles used in the mechanization of present hand operations, and of new and modified operations resulting from progress in other areas of research. Mechanization is often done to meet an emergency shortage of labor, resulting in a crude operation with accompanying crop losses. It is essential that research develop mechanization principles prior to emergencies.

c. Goal IV, Product Development and Quality: The objective of this goal is to expand the demand for farm products by developing new and improved products and processes and enhancing product quality. Within this objective, the research effort would be aimed at (1) developing varieties and strains of crops having attributes that meet the preferences and desires of consumers; (2) improvement

of production practices, processing methods and marketing procedures so as to preserve or enhance inherent qualities of farm products; (3) development of new and improved products from agricultural commodities by tailoring products to meet consumer preferences and by increasing product utility for the consumer per unit of input.

The objective was further broken down into 12 research problem areas of which three apply to sugar crops: RPA 406, New and Improved Food Products from Field Crops; RPA 407, New and Improved Feed, and Industrial Products from Field Crops; RPA 408, Quality Maintenance in Marketing Field Crops. RPA 405, pertaining to production for consumer acceptability is discussed under Goal III in this report.

Raw sugar manufacture and refining nearly doubles the value of sugar crops. There have been few changes, however, in conventional methods of manufacturing sugar or in by-product utilization. This is a challenge as much as it is statement of fact. Developments in processing technology have not kept pace with industry needs.

New processing problems are developing as old ones become more acute. This situation results from factors such as labor shortage, higher trash content of cane, lower quality of sugarbeets, factory mechanization, and air and stream pollution. These factors in addition to motivating demands for process improvements also motivate demands for more profitable uses and more efficient marketing for beet residues, bagasse, molasses, muds, and waste waters.

A new concept of sugar processing is needed for the future. The size of processing plants will enlarge, thereby, increasing the investment. Labor like capital deserves year-long employment. We should envision large automated factories that operate throughout the year. Perhaps, these can be flexible enough to handle cane, beets, sweet sorghum, and corn, or other new crops.

d. <u>Goal V, Efficiency in Marketing</u>: Under this broad goal for all of agriculture are the following objectives: (1) to provide farmers with better market guides for making production and marketing decisions; (2) improved quality and availability of production items and services; (3) facilitate distribution of products; (4) improve the quality and availability of products to the consuming public; and (5) reduce the resources required in the transfer of products from farm to consumer.

These objectives were broken down further into ten research problem areas of which two were assigned to this Task Force. They are RPA 501, Improvement of Grades and Standards; and RPA 504, Physical and Economic Efficiency in Marketing Field Crops. The other RPA's pertain to supply, demand, and price analysis (506); competition (507); domestic market development (508); marketing firm and system efficiency (509); and farmer bargaining power (510). These problem areas pertain to the entire agriculture marketing system of which marketing sugar crops is a part.

As expressed in the statements under RPA's 501 and 504, the sugar industry believes that it has developed a highly efficient distribution system for refined sugar. However, a modest research program in these problem areas is in the public interest. Such research will be directed to keep abreast of technological and economic developments that influence national policies or programs for the highly regulated sugar industry.

## D. Review of Research Problem Areas

Each research problem area assigned to the Sugar Crops Task Force is treated individually in the following three sections of this report dealing with (1) sugarbeets; (2) sugarcane; and (3) sweet sorghum. The summary tables on the next two pages show the recommendations of the Task Force in terms of scientist-man-years for each research problem area assigned for the entire industry and by each of the three crops.

TABLE 1

JOINT TASK FORCE ON SUGAR CROPS RESEARCH

Summary of Inventory and Recommended SMY's

| | Research Problem Area | 1966 1/ | | | 1977 2/ | | | 1977 3/ | |
|---|---|---|---|---|---|---|---|---|---|
| | | SAES | USDA | TOTAL | SAES | USDA | TOTAL | TOTAL | Increase over 1966 |
| 207 | Control of Insect Pests | 5 | 9 | 14 | 10 | 18 | 28 | 30 | 16 |
| 208 | Control of Diseases | 11 | 30 | 41 | 17 | 42 | 59 | 61 | 20 |
| 209 | Control of Weeds, Etc. | 6 | 3 | 9 | 9 | 5 | 14 | 26 | 17 |
| | Subtotal - Protection | 22 | 42 | 64 | 36 | 65 | 101 | 117 | 53 |
| 307 | Biological Efficiency | 35 | 15 | 50 | 39 | 19 | 58 | 71 | 21 |
| 308 | Mechanization | 3 | 2 | 5 | 3 | 2 | 5 | 14 | 9 |
| 309 | Systems Analysis | 2 | 0 | 2 | 2 | 0 | 2 | 4 | 2 |
| 405 | Consumer Acceptibility | 1 | 4 | 5 | 1 | 4 | 5 | 7 | 2 |
| | Subtotal - Production | 41 | 21 | 62 | 45 | 25 | 70 | 96 | 34 |
| 406 | Food Products | 5 | 2 | 7 | 5 | 2 | 7 | 15 | 8 |
| 407 | Feed & Nonfood Products | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 |
| 408 | Quality Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| | Subtotal - Prod. Develop. | 5 | 2 | 7 | 5 | 2 | 7 | 22 | 15 |
| 501 | Grades and Standards | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 |
| 504 | Market Efficiency | 2 | 1 | 3 | 2 | 1 | 3 | 5 | 2 |
| | Subtotal - Marketing | 3 | 1 | 4 | 3 | 1 | 4 | 6 | 2 |
| | GRAND TOTAL | 71 | 66 | 137 | 89 | 93 | 182 | 241 | 104 |

1/ Inventory of Agricultural Research, Volume I, Table I, June 1967.

2/ A joint committee representing the Experiment Station Committee on Organization and Policy, and the USDA, reviewed manpower allocations and recommended the SMY's shown.

3/ Task Force recommendations. Allocations between State and Federal not made.

TABLE 2
JOINT TASK FORCE ON SUGAR CROPS RESEARCH
Summary of Inventory and Recommended SMY's by Crops

| RPA | Sugarbeets | | | Sugarcane | | | Sweet Sorghum | | |
|---|---|---|---|---|---|---|---|---|---|
| | FY 66 1/ | FY 77 2/ | Increase | FY 66 1/ | FY 77 2/ | Increase | FY 66 1/ | FY 77 2/ | Increase |
| 207 Control of Insects | 5 | 13 | 8 | 9 | 17 | 8 | 0 | 0 | 0 |
| 208 Control of Diseases | 20 | 30 | 10 | 19 | 28 | 9 | 2 | 3 | 1 |
| 209 Control of Weeds, Etc. | 5 | 12 | 7 | 4 | 14 | 10 | 0 | 0 | 0 |
| Total Protection | 30 | 55 | 25 | 32 | 59 | 27 | 2 | 3 | 1 |
| 307 Biological Efficiency | 14 | 26 | 12 | 34 | 42 | 8 | 2 | 3 | 1 |
| 308 Mechanization | 1 | 5 | 4 | 4 | 9 | 5 | 0 | 0 | 0 |
| 309 Systems Analysis | 1 | 2 | 1 | 1 | 2 | 1 | 0 | 0 | 0 |
| 405 Consumer Acceptability | 4 | 5 | 1 | 1 | 2 | 1 | 0 | 0 | 0 |
| Total Production | 20 | 38 | 18 | 40 | 55 | 15 | 2 | 3 | 1 |
| 406 New & Improved Foods | 2 | 6 | 4 | 5 | 9 | 4 | 0 | 0 | 0 |
| 407 New & Improved Nonfoods | 0 | 3 | 3 | 0 | 2 | 2 | 0 | 0 | 0 |
| 408 Quality Maintenance | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| Total Development | 2 | 10 | 8 | 5 | 12 | 7 | 0 | 0 | 0 |
| 501 Grades and Standards | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 504 Marketing | 1 | 3 | 2 | 2 | 2 | 0 | 0 | 0 | 0 |
| Total Marketing | 1 | 3 | 2 | 3 | 3 | 0 | 0 | 0 | 0 |
| GRAND TOTAL | 53 | 106 | 53 | 80 | 129 | 49 | 4 | 6 | 2 |

1/ Inventory of Agricultural Research, Volume 1, Table 1, June 1967.
2/ Sugar Crops Task Force Recommendation.

# II. SUGARBEET RESEARCH GOALS AND PROBLEM AREAS

# RPA 207 CONTROL OF SUGARBEET INSECTS

## 207-A Nonchemical Methods

SITUATION: Sugarbeets are infested by a number of insect and mite species. Current control practices involve chemicals as principal weapons in combating arthropod pests. In spite of the use of pesticides, insect losses remain high. Additional problems are associated with the use of pesticides. Some of these are potentially hazardous residues, insect resistance, environmental pollution, toxic effect on beneficial insects, and the fact that only temporary relief is afforded by chemical control procedures.

OBJECTIVE: Develop improved methods of sugarbeet insect control by nonchemical means. This includes the use of biotic agents, attractants, sterility techniques, bioenvironmental methods, and varietal resistance.

RESEARCH APPROACHES:

A. Investigate the role of predators, parasites, and pathogens in limiting the development of sugarbeet insect populations. Determine the biological and environmental factors which influence parasitism, predation, and pathogen infection under field conditions.

B. Determine the feasibility of supplementing naturally occurring biotic agents with beneficial insects or pathogens that are mass-reared or cultured in the laboratory.

C. Determine the potential of introducing new parasites and predators for regulating sugarbeet insect populations.

D. Determine the potential use of physical and/or chemical attractants for controlling insect populations.

E. Determine the feasibility of sterility techniques for area-wide suppression of insect pest populations.

F. Investigate bioenvironmental methods for suppressing sugarbeet insect populations through elimination or

replacement of expendable host plants, strategic application of insecticides to overwintering host plants, and other cultural practices.

G. Determine the potential of varietal resistance for reducing sugarbeet insect populations, including studies of the type and nature of resistance and the feasibility of incorporating resistance factors into commercially acceptable varieties.

H. Determine the potential of chemical and physical attractants in sugarbeet insect control programs.

207-B Improved Chemical and Integrated Methods

SITUATION: The principal means of controlling sugarbeet insect pests is by use of insecticides. Insect species have become resistant to insecticides that formerly gave effective control. There is a continual need for new formulations to control insect pests.

OBJECTIVE: Develop selective chemicals for individual insect species that are degradable by the systems of higher animals, low in mammalian toxicity, and economical.

RESEARCH APPROACHES:

A. Evaluate new materials for sugarbeet insect control and residue safety.

B. Determine the effect of such chemicals on populations of naturally occurring parasites and predators.

C. Determine the threshold of economic insect damage requiring the use of insecticides.

D. Develop integrated control systems through the judicious use of insecticides which have a minimum effect on biotic agents.

E. Determine the feasibility of integrating chemical control methods with sterility, attractants, and other methods to exert maximum pressure on insect populations.

## 207-C Biology, Ecology, and Population Dynamics of Insect Populations

SITUATION: Detailed knowledge of specific insect species is necessary to develop improved nonchemical or integrated methods of control. Most insects that attack sugarbeet also feed on a number of other crops. The insect population is regulated through management of the entire range of cultivated and wild host plants. All related parasites, predators, and pathogens have an effect. Detailed studies on the biology, ecology, and population dynamics of these species can reveal weak links in the development of insect populations and other fundamental facts essential for effective control.

OBJECTIVE: Develop information on the occurrence, seasonal distribution, abundance, behavior, and other biological and ecological characteristics of sugarbeet insect populations.

RESEARCH APPROACHES:

A. Develop information on the biology of insect pests, including mating, feeding, migration, host plants, and factors regulating the development of insect populations.

B. Determine the economic threshold of sugarbeet insect populations.

C. Determine the occurrence, distribution, and abundance of pest species and accurate methods of determining population density.

## RPA 208 CONTROL OF SUGARBEET DISEASES

### 208-A Resistant Varieties

SITUATION: The sugarbeet is susceptible to a number of highly destructive diseases. Resistant varieties are an effective means of control. Profitable production of sugarbeets in Western United States requires varieties resistant to the curly top disease. Varieties more resistant to virus yellows and mosaic are needed to reduce extensive losses that may be as high as half the crop. Germ plasm resistant to sugarbeet nematodes is present in wild species of beet, but it has not yet been incorporated into commercial varieties. Cercospora leaf spot resistance is available in commercial beets, but the level must be increased. Resistance to destructive seedling diseases and to root rotting organisms has not been developed adequately. The rapid changes in sugarbeet varieties required by the development of monogerm types and hybrids present a formidable challenge to plant breeders in maintaining present levels of disease resistance. A greater challenge is the need to develop varieties with even better adaptation and resistance systems.

OBJECTIVE: Identify resistance systems and incorporate them into sugarbeet varieties with high sucrose and yield potential for different production areas.

RESEARCH APPROACHES:

A. Identify and retain genetic material with high levels of resistance to sugarbeet diseases for use in breeding programs.

B. Study the inheritance and functional basis of host reactions to pathogens and the effects of environmental and other factors on expression of resistance or susceptibility.

C. Conduct breeding programs to maintain and increase sugarbeet resistance to disease.

## 208-B Crop Sequence and Other Management Practices

SITUATION: Profitable sugarbeet production depends on effective use of crop rotation and other management practices to control diseases. The cyst nematode is controlled economically only by strict rotation of crops. The spread of Rhizoctonia root rot is deterred by the same means. As an example, crop management on a district basis is used in California to reduce losses from virus yellows. Beet-free periods are needed to break the vector cycle. Even irrigation practices have an influence on such diseases as leaf spot.

OBJECTIVE: Study production practices and management in relation to epidemics of sugarbeet diseases and develop new economic techniques that will reduce disease loss.

RESEARCH APPROACHES:

A. Establish practical cultural methods for reducing losses from nematodes by conducting studies on their biology. Determine factors involved in the persistence of nematodes and their increase in infested soils.

B. Determine how management practices such as virus-free periods and dates of planting can reduce disease incidence and how to use such information in profitable sugarbeet production. Develop new concepts for disease control by management of the factors regulating the dynamics of virus-vector populations and thus the spread of viruses.

C. Develop sanitary measures for disease control based on epidemiology.

D. Study the effects of crop rotation on pathogenic soil fungi. Determine the effect of such treatments on populations and persistence of these fungi.

E. Study the effect of management practices such as irrigation and spacing on disease control by altering the environment.

## 208-C Identification and Characterization of Agents Causing Diseases

SITUATION: Complexes of strains or races of pathogenic agents varying in destructiveness, rate of spread, and host range cause diseases of sugarbeet. The problem is complex because they mutate, producing more highly virulent pathogens. Control by breeding and crop management depends on a thorough, up-to-date knowledge of the situation. This requires keeping abreast of changes in the pathogen complex which result from mutation or introduction of entities from abroad.

OBJECTIVE: Identify, characterize, and determine the capabilities of biologic forms of pathogenic agents affecting the sugarbeet and obtain basic information essential for control.

RESEARCH APPROACHES:

A. Determine the range and mechanism of variation in strains of pathogenic agents and the disease potential of different variants.

B. Interaction of pathogenic agents in the production of disease, such as apparent increase in susceptibility of nematode-infested plants to root rotting organisms and the increase in susceptibility of yellows-infected plants to Cercospora leaf spot.

C. Basic studies on the nature of viruses and virus diseases as related to epidemiology.

D. Identification of the factors involved in the maintenance of viruses, virus reservoirs, and vectors in desert and non-desert areas, particularly as related to curly top and virus yellows diseases.

## 208-D Physiological Bases in Disease Resistance

SITUATION: Specific mechanisms have been identified in growing plants that impart resistance to a particular disease. This principle has not been developed for the sugarbeet though a start has been made. Some of the chemical factors involved in resistance to virus yellows and leaf spot are being determined. These beginnings are extensive enough to give promise of substantial progress in the future. The efficiency of breeding for disease resistance would be improved if selection could be made for precise physiological systems.

OBJECTIVE: Determine the nature of disease resistance mechanisms in sugarbeet.

RESEARCH APPROACHES:

A. Establish a chemical base in growing plants that impart susceptibility or resistance to specific diseases. Determine the biochemical effects of systemic agents such as viruses. Correlate changes with disease reaction.

B. Determine the biochemical effects of parasitism by non-systemic agents such as *Cercospora* and *Rhizoctonia*. Determine the mechanisms responsible for prevention of parasitism.

C. Correlate chemical changes in the stored beet with parasitism by rotting organisms.

## 208-E Identification and Study of Potentially Hazardous Foreign Diseases

SITUATION: The disastrous introduction and spread in the United States of the sugarbeet cyst nematode, European in origin, is evidence of the threat of foreign diseases. Highly destructive sugarbeet diseases occur in South America and the Mediterranean area that are not known in the U.S. Among these are yellow wilt in Argentina and Chile; Argentine curly top in Argentina, Brazil, and Uruguay; and Brazilian curly top in Brazil. Also, little is known about a curly top virus with a wide geographic distribution from the Mediterranean area eastward through India. There are six Mediterranean species of leafhoppers that may be vectors of the North American curly top virus. All the foreign diseases mentioned are transmitted by leafhoppers that could easily be transported by plane with the viruses to the United States.

OBJECTIVE: Institute studies that will minimize the danger of foreign pathogenic agents.

RESEARCH APPROACHES:

A. Screen U.S. varieties in other countries where dangerous diseases occur.

B. Study the nature of the disease and its incitant and epidemiology in the areas where it is a problem.

C. Initiate breeding programs in cooperation with foreign scientists, to develop resistant lines of sugarbeets for the United States.

D. Develop new methods to prevent the introduction of new diseases.

## 208-F Epidemiology

SITUATION: Sugarbeet diseases vary in severity, depending on climate. Leaf spot in the Red River Valley may be absent or be a costly problem, depending on the season. Virus yellows may take one-half the crop in California, or it may be negligible. Plant disease forecasting is a potentially useful management tool to reduce disease losses and is essential to the development of improved control systems. The information to support reliable disease forecasting of sugarbeet diseases, however, is deficient. The effect of climate on vector-virus-host interaction is poorly understood. Water-temperature interactions in relation to leaf spot incidence are basic to effective spray programs. Sugarbeet disease losses will be more effectively reduced as we understand the relationship of climate to disease.

OBJECTIVE: Develop criteria for predicting the years and period epidemics will occur.

RESEARCH APPROACHES:

A. Determine the environmental conditions that lead to epidemic pathogen populations.

B. Determine the environmental and other ecologic conditions that lead to high populations of the vectors of virus diseases.

C. Establish a controlled environment facility to test several environmental systems simultaneously. Establish predictive models.

# RPA 209 - CONTROL OF WEEDS IN SUGARBEETS

## 209-A Herbicide Evaluation and Residue Detection

SITUATION: Sugarbeet areas in the United States encompass a wide range of environment. Also, crop management practices differ widely, as for example, in the Red River Valley and the Imperial Valley. The sugarbeet weed problem is complex because a large number of genera and species are involved. These include pigweed, lambsquarters, foxtails, mustard, kochia, barnyardgrass, wild oats, Russian thistle, and others. New herbicides require precise evaluation for use on problems specific to each area.

Herbicides and other crop protection chemicals also may leave residues in soil that are harmful or beneficial to sugarbeets and subsequent crops or contaminate drainage waters. Knowledge about the fate and degradation of such materials in treated soils and in plant material is basic to their use. The producer seeks to prevent or lessen injury to the sugarbeet plant and subsequent crops. The consumer must be assured of a safe product. The public is concerned about contamination of the environment.

OBJECTIVE: Develop more reliable, safe, selective herbicide treatments for both broad-spectrum control and control of individual species of problem weeds. Determine the fate of herbicides applied for weed control in sugarbeets and the effect of residues on subsequent crops in a rotation. Evaluate persistence and degradation rates for single herbicides and combinations with other crop protection chemicals.

RESEARCH APPROACHES:

A. Conduct laboratory and field research to evaluate new herbicides for crop tolerance and herbicidal activity against specific problem weeds.

B. Evaluate herbicide formulations, dosages, application timing and method, including combinations of selective herbicides applied simultaneously or as split applications.

C. Analyze soil and plant materials to determine levels of chemical residues from herbicides applied to control weeds

in sugarbeets and other crops under different environmental conditions. Determine the effect on yield.

D. Investigate the interactions between herbicides and other crop protection chemicals (insecticides, fungicides and liquid fertilizers) with respect to effects on residues in soil and in plants. Investigate the metabolism of herbicides in plants to facilitate the development of techniques to avoid harmful residues in soils and in plant materials.

E. Study the effect of repeated herbicide application on sugarbeets and other crops planted in subsequent seasons.

F. Contribute to studies of pesticide fate in large-scale ecosystems.

## 209-B Mode of Action of Herbicides in Natural Environment

SITUATION: Herbicides used for weed control in sugarbeets sometimes injure the crop or fail to control the weeds. The problem is complex and difficult to understand because basic information is lacking. Particularly urgent is the need to determine mechanisms governing postemergence control of dicotyledonous weeds. Data are needed on the uptake, movement, and dissipation of herbicides applied to both soil and foliage. Knowledge about the mechanisms involved in herbicide-plant interactions would improve the effectiveness of their use. It should enable scientists to develop improved herbicides.

OBJECTIVE: Determine the mechanisms regulating herbicide action.

RESEARCH APPROACHES:

A. Identify biotic and climatic variables affecting activity of herbicides through laboratory and field studies.

B. Identify soil and climatic variables affecting activity of herbicides through laboratory and field studies.

C. Determine absorption-desorption equilibria for herbicides, using soil fractions from production areas, as these mechanisms may affect dosage responses.

D. Determine the effects of herbicides on metabolic systems of plants and on physical-chemical systems in the soil.

E. Investigate mechanisms of herbicide action on plants and study detoxification of herbicides by plants to obtain information on the basis of selectivity.

## 209-C Herbicide Application and Placement Methods

SITUATION: The placement of herbicides in the soil or on weed foliage may affect performance more than the type of toxicant or rate of application. The volatility, water solubility, and degree of adsorption by soil are some of the characteristics of a chemical that determine whether a herbicide should be incorporated in soil. Site of adsorption by crop and weeds and site of action in crop and weeds must be considered also. Soil moisture loss attending the incorporation of materials may limit herbicidal responses in semiarid regions. Incorporation affects crop tolerance and weed control effectiveness differently for different materials. In some instances, the change is beneficial; in others, detrimental. Results indicate that incorporation of preplant materials is necessary only with certain herbicides. Furthermore, materials respond differently, depending on the type of incorporation device and soil composition. Placement of herbicides as postemergence treatments on weed foliage also influences activity according to the age, anatomy, and morphology of the plant. The development of new incorporation tools and techniques should improve the performance of some herbicides. Research on placement of herbicides on particular parts of emerged weeds should lead to more efficient techniques for applying postemergence treatments.

OBJECTIVE: Enhance chemical weed control by improving or developing new application and placement techniques.

RESEARCH APPROACHES:

A. Determine effective placement and application methods for specific herbicides in different soil types.

B. Investigate high-pressure, low-volume liquid, foam, and injector applicators.

C. Investigate the influence of cultural practices, such as type of irrigation, drainage, and time of planting, as well as type of seedbed, with respect to effects on placement of herbicides.

D. Investigate anatomical and morphological features of species to discover more efficient ways of placing herbicides applied as postemergence treatments.

209-D Physiology and Ecology of Weeds Troublesome in Sugarbeets

SITUATION: Sugarbeets and weeds differ in many aspects of their physiology and ecology. Inherent weaknesses have been discovered in some pests that permit a precise treatment with a specific herbicide that is selectively effective. The factors governing dormancy and germination of weed propagules are potential tools to be manipulated for control of weeds. Development of improved treatments for control of weeds will be facilitated by a better understanding of the differences between sugarbeets and weeds.

OBJECTIVE: To discover whether differences exist between weeds and sugarbeets with respect to seed germination, physiological processes, and response to ecological factors useful for improving the selectivity and effectiveness of weed control treatments.

RESEARCH APPROACHES:

A. Study the physiology and morphology of weeds and sugarbeets at all stages of growth with respect to differences that might affect selective control of particular weeds with chemical or cultural means.

B. Study the nature and duration of dormancy and germination of weed seeds or other propagules.

C. Investigate growth stages in relation to biochemical changes in the plant that might indicate weak points in the life cycle.

## RPA 307 BIOLOGICAL EFFICIENCY

### 307-A Genetics and Interspecific Hybrids

SITUATION: Historically, the success or failure of the sugarbeet industry in a geographic area has rested on the development of adapted varieties. When the enterprise was in its early years, the selection of varieties was made from heterozygous lines. The sophistication of industry today is matched by precise methods of producing hybrid varieties utilizing sterility-fertility factors. The full expression of a genotype for yield and quality is possible only when there are associated genetic traits for resistance to pests. Hence the search for full biologic efficiency requires concomitant traits providing protection from production hazards. The new germ plasm within the genus *Beta* holds great promise to improve biologic efficiency.

OBJECTIVE: Develop new sugarbeet breeding stocks with higher yield and quality characteristics and with associated pest protective mechanisms which are adapted to different areas of production.

RESEARCH APPROACHES:

A. Evaluate germ plasm for yield and quality potential and genes for pest resistance.

B. Initiate breeding programs to incorporate improved traits in desirable breeding stocks of sugarbeet.

C. Determine the sterility-fertility characteristics of new germ plasm.

D. Determine bolting resistance of new germ plasm.

E. Examine the specific and general combining ability of new material at the diploid and other ploidy levels.

## 307-B <u>Methods of Breeding and Chemical Genetics</u>

SITUATION: Fundamental breeding procedures and genetic principles established in other crops have not been fully exploited or developed in sugarbeets. The vast array of known desirable characteristics that must be assembled for developing sugarbeet varieties with maximum yields of sucrose require radically new methods of breeding. It appears certain that many of the desirable characteristics will be manifested in biochemical and physiological associations. These could serve the purpose of facilitating the identification, synthesis, and utilization of superior germ plasm. The genetic control and inheritance of these quality factors can be determined only by exhaustive testing under variable conditions of environmental exposure. The methodology developed under this program will enhance the chances of combining new material from basic genetic studies with disease resistance and improved processing qualities.

OBJECTIVE: To acquire better methods for genetic control of the chemical and physiologic components of sugarbeets that control yield, quality, and pest protection.

RESEARCH APPROACHES:

A. Expand the present search for applicable breeding techniques for the control of desirable heritable characteristics.

B. Extend studies on the inheritance of purity and impurity components; include further definition of the latter.

C. Polyploidy, as noted under basic genetics, should be included in research on breeding methods for a precise comparison of equivalent 2n, 3n, and 4n hybrids.

307-C Sugar Synthesis, Growth Regulators, Respiration and Storage

SITUATION: The discovery of growth-controlling chemicals and studies on their mode of action were the basis for practical applications in the agricultural industry. There is much yet to be learned about the effects on sugar. The translocation of the products of photosynthesis from the site of production to the storage and growing areas is not fully understood. A method to control this in the green plant has yet to be discovered. It is not clear whether the sucrose, which accumulates in the root, was transported there from the leaves or whether it is a product of synthesis. It subsequently follows that all the factors affecting sucrose degradation in stored roots awaiting processing are not known. An understanding of the sucrose synthesis system as it may be affected by growth regulators could provide knowledge with which postharvest losses can be reduced or eliminated.

OBJECTIVE: To intensively study 1) synthesis and translocation of sucrose, 2) growth regulators and/or metabolic inhibitors, and 3) respiration of the sugarbeet during growth and while in storage, to increase unit production of sugar per acre and reduce the loss of sugar during the harvest processing interim.

RESEARCH APPROACHES:

A. Study sucrose translocation, using tagged materials.

B. Study the transport of sucrose, with or without the influence of various growth regulators, into the storage root.

C. The fate of sucrose in the beet under variable environmental conditions of growth and storage should be determined.

D. Physiological-biochemical studies should be conducted in cooperation with geneticists to determine differences in and suitability of genotypes. Determine whether enzyme differences are related to heterosis.

## 307-D Sugarbeet Quality and Environmental Influences

SITUATION: The nebulous term "quality" involves high sucrose levels and low nonsucrose constituents that interfere with sucrose extraction. The total environmental profile of temperature, sunlight, water, nutrients, and the insect-disease spectrum influences quality. The highest gross sugar-producing varieties may not give the highest recoverable sugar, due to fluctuating levels of nonsucrose constituents affected by one or more environmental factors. The interrelation and proportionality of these constituents are not completely known. As a matter of fact, the total composition of the sugarbeet root has not been adequately described.

OBJECTIVE: To determine the separate and combined effects of environment on the factors that determine quality.

RESEARCH APPROACHES:

A. Study environmental factors that cause wide fluctuations in yield between any two given years with the same varieties.

B. A model of the growth influencing factors should be developed to pinpoint those that are most influential on growth and maturity. This should be followed by a genetic analysis under controlled environmental conditions.

C. New breeding methodology should be exploited in producing genotypes that are "tailor-made" for specific geographic areas.

## RPA 308 MECHANIZATION

### 308-A Mechanization of Production

SITUATION: Most phases of sugarbeet culture are mechanized, but considerably more effort is needed before hand labor can be eliminated. Seed planters, for example, cannot accurately place single germ seeds at the desired final spacing. Germination of these seeds and subsequent stand are not good, due to seedbed preparation practices with present equipment. More reliable herbicide application methods are also needed. Improvement is needed in topping as it relates to utilization of tops, to increase the value of the crop. Cleaning and storage of sugarbeets could be improved by new methodology.

OBJECTIVE: Develop seedbed preparation and planting equipment which, combined with improved emergence techniques, will permit planting to a stand. Improve methods of topping to allow better utilization of tops. Improve cleaning and storage methods of sugarbeets.

RESEARCH APPROACHES:

A. Seek methods of improving seedbed preparation, especially on heavy soils, to facilitate accurate seed placement.

B. Improve planters for accuracy at high speeds in planting depth, cell fill and seed spacing, using raw or coated seed.

C. Investigate environmental and mechanical requirements for planting to a stand.

D. Develop more efficient and economical equipment for herbicide incorporation and improve present cultivating equipment for higher speeds.

E. Develop lighter weight equipment for accurately applying chemical herbicides or insecticides in narrow row bands while fields are wet.

F. Improve efficiency of top-saving equipment.

G. Develop more effective beet cleaning devices, better mechanical methods of handling and transporting, and methods of preventing deterioration during storage.

H. Develop methods of determining and eliminating spoiled or poor quality beets before processing.

## RPA 309 SYSTEMS ANALYSIS

### 309-A Systems Analysis in Production

SITUATION: Sugarbeet producers must choose among many alternatives for selection of a crop rotation, cropping practices, planting time, row spacing, seeding rates, weed control and fertilizer practices, irrigation regime, and size and capacity of machinery. Proper selection for the various alternatives depends on the relation of cropping practices to disease and pest control, crops available, labor and capital requirements, production costs, and possible crop returns. Mathematical models are needed to simulate the variables and alternatives in various production systems to make possible the intelligent comparison of the profitability of various alternatives. A true measure of profitability becomes of vital importance in the price-cost squeeze affecting agriculture today.

OBJECTIVE: Combine production practices, capital investments, and labor availability and utilization to provide optimum income and avoid disease and pest problems inherent in continuous cropping.

RESEARCH APPROACHES:

A. Use mathematical models for examining the various production systems and for evaluating individual practices within a system to identify factors requiring additional research.

B. Study the feasibility of various combinations of production systems to determine which practices result in the most productive and economical combinations. Such studies might include, but not necessarily be limited to, an examination of the following production factors in various cropping systems:

   1. Production costs and cash returns.

   2. Interrelation of control of various pests and diseases.

3. Economic use of machinery.

4. Labor problems and their relationship to production procedures.

5. Methods of weed control and fertilizer practices.

6. Amount and methods of irrigation in relation to efficiency of water use.

7. Various combinations of cultural practices in sugarbeet production, including management of soils, crop residues, soil fertility, plant populations, irrigation and crop sequence.

## RPA 405 CONSUMER ACCEPTABILITY

### 405-A Production of Sugarbeets with Improved Quality

SITUATION: Quality problems in sugarbeets relate to total sucrose content and the amount and nature of soluble solids. We now produce sugarbeets with more sucrose per acre. We have not, however, been able to produce varieties that improve sugar recovery in the processing plant. This is due to a lack of knowledge about specific constituents affecting quality. There is a poor understanding of the metabolic changes that take place in a beet after harvest. Analytical methodology is woefully inadequate.

OBJECTIVE: Develop varieties and cultural practices that will improve processing qualities after prolonged storage. Increase sucrose and decrease nonsucrose solids. Develop methodology to measure chemical and other factors critical to sugar recovery.

RESEARCH APPROACHES:

A. Identify genotypes containing significant chemical constituents in higher or lower than normal concentrations and use such genotypes to breed agronomically superior varieties.

B. Determine the significance of environmental factors during crop production on the levels of chemical constituents of special significance in processing ability and resistance to change in storage.

C. Devise new or modified analytical techniques appropriate to support approaches A and B.

# RPA 406 FOOD PRODUCTS

## 406-A Chemical Composition and Physical Properties of Sugarbeets and Liquors

SITUATION: The nonsugar chemicals in beets may cause 20% loss of sugar in molasses. Removal of these compounds by chemical or physical means is one method of control; selecting beets with higher purity is another. Agronomic practices can improve quality as well. How does composition change during processing? How is quality changed by breeding? How do agronomic methods affect beet quality? All of these improvements require a better knowledge of the composition of beets and liquors.

OBJECTIVE: To determine the complete chemical composition of sugarbeets and process liquors and relate the effects of nonsucrose chemicals to sugarbeet quality and processing characteristics.

RESEARCH APPROACHES:

A. Isolate and identify sugar and nonsugar chemicals in sugarbeets.

B. Develop new and simplified methods of analysis for beet constituents.

C. Develop techniques useful to agronomists and geneticists for improving quality.

406-B Losses of Sugar from Factory Sugarbeets

SITUATION: Manufacturers have increased their plant capacities and operate for a longer period to balance rising processing costs. This expansion has required a large factory-beet storage inventory and long storage periods. Losses of sugar from factory beets by microbiological action, direct respiration, and biochemical sugar transformations are aggravated by increased length of storage periods. Direct sugar losses and the deleterious changes that occur in factory beets could be lowered if the processes were more completely understood and preventative methods applied.

OBJECTIVE: To determine the most effective means to depress microbiological, respiratory, and biochemical losses of sugar from factory beets.

RESEARCH APPROACHES:

A. Study means of controlling microbiological losses of sugar in sugarbeets.

B. Determine the nature and means of preventing biological sugar transformations.

C. Develop means of reducing aerobic respiration of beets and other techniques to control direct sugar losses.

## 406-C Improved and New Processing Methods for Sugarbeets

SITUATION: Manufacturers of beet sugar must increase processing efficiency. Research is needed to stop the decline of sugar recovery. The research for improvements in present processing technology and automation must be explored in detail. Radically new processes may be essential. Improvements in established methods must be made if processing technology is to progress.

OBJECTIVE: Improve established procedures and develop new economic methods that will increase the amount of extractable white sugar from sugarbeets.

RESEARCH APPROACHES:

A. Study ion-exchange procedures for separating nonsugars from processing liquors.

B. Explore ion-exclusion as an adjunct for purifying sugar solutions.

C. Study pretreatment of cossettes with lime or other protein precipitants as a means of purifying sugar-containing extracts from beets.

D. Conduct basic research on the Steffen process of sugar recovery from molasses to increase its efficiency.

E. Study and evaluate the concentration and purification of sugar juices, using reverse osmosis.

# RPA 407 FEED AND NON-FOOD PRODUCTS

## 407-A Chemical Reactions of Sugar: Sucrose Chemicals as Non-Food Industrial Products

SITUATION: Chemical uses for sugar consume about 0.2 percent of the annual 10 million tons consumed in the nation. Recently, successful introduction of useful sucrochemicals in industry has been made. Products presently in the research stage offer promise that the industrial uses for sucrose will increase. Sucrose is a unique chemical. It is available in large quantities, at a low price, and in a pure form. Successful research could provide an expanded and significant non-food market for sugar.

OBJECTIVE: Transform sucrose into high-value industrial products for use in the chemical industry.

RESEARCH APPROACHES:

A. Prepare sucrose esters, using low-cost, fatty acid derivatives, and evaluate properties of products.

B. Prepare sucrose esters with varying degrees of substitutions and evaluate properties of products.

C. Synthesize organic acids and other chemical intermediates from sucrose and evaluate their properties.

D. Prepare polymers containing sucrose or derivatives and determine their properties.

E. Conduct pilot plant studies on products that appear to have industrial possibilities with the view to lower costs of production.

407-B Industrial Products from Beet Pulp

SITUATION: A million tons of dried beet pulp is available annually for feed or industrial use. Carbohydrates such as cellulose, pectin, araban, and galactan make up more than three-quarters of the dried weight of pulp. Each of these carbohydrate polymers has distinctive properties and could be of commercial value. Beet pulp is currently used only as livestock feed. Alternative uses would broaden the base of value.

OBJECTIVE: Develop new industrial uses for beet pulp and its constituents.

RESEARCH APPROACHES:

A. Develop economic procedures for extraction, purification, and use of araban gum.

B. Develop procedures for extraction of the pentose sugar, arabinose, and prepare industrial chemical derivatives.

C. Evaluate the potential of beet pulp and processed beet pulp as ingredients in pressed boards.

D. Develop means of converting pulp to a hydrophilic thickening agent and as an ingredient in fire retardants.

E. Devise means of extracting sugarbeet pectin and converting it to a valuable gelation agent.

# RPA 408 MARKET QUALITY

## 408-A Market Quality

SITUATION: Postharvest sugar loss from respiration and spoilage of beets in storage piles is enormous. Moreover, degradation products from the breakdown of sucrose while beets are in storage lower extraction efficiency, resulting in additional loss. The combined effects exceed 8% of the value of recoverable sugar when beets enter storage. Present methods designed to reduce respiration rates and freezing and thawing of beets in storage piles are unsatisfactory. New approaches and solutions to sugarbeet storage problems must be found. The acceptance of controlled atmosphere storage systems for highly perishable crops, such as fresh fruits and vegetables, suggests that similar systems should be extensively examined and evaluated for application to sugarbeet storage. In addition, research is urgently needed to determine not only the nature of fundamental physiological processes that occur during storage, but also the identification of specific carbohydrate degradation products that are produced from the breakdown of sucrose during storage.

OBJECTIVE: Develop new techniques and procedures for handling beets in storage that will permit harvest quality to be maintained throughout storage; develop suitable methods for the identification of carbohydrate degradation products that arise from the breakdown of sucrose in storage.

RESEARCH APPROACHES:

A. Evaluate new techniques, including the use of controlled atmosphere and mechanical refrigeration, for the development of economically feasible storage systems that will minimize sugar losses in storage.

B. Develop practical and accurate methods for identification of carbohydrate degradation products that develop from the breakdown of sucrose in storage piles.

## RPA 501 GRADES AND STANDARDS

### 501-A Improvement of Grades and Standards for Sugarbeets

SITUATION: Grades and standards for sugarbeets are essential for the division of proceeds among claimants, including the various growers of a factory area and the factory itself. Analytical procedures and standards of sugarbeet quality are highly developed and extensively used, including the employment of these procedures and standards in the U.S. Sugar Act program. Work in this field has been carried to such a high degree of development that no additional research effort on sugarbeet grades and standards is needed.

The present level of research should be continued. In view of the changing technology and market conditions, such research is in the public interest. The research should be distributed according to the need and contribution of the total sugar supply.

## RPA 504 MARKETING EFFICIENCY

### 504-A Physical and Economic Efficiency in Marketing Sugarbeets

SITUATION: Rapid development of the food processing industry brought about dramatic changes in the distribution of refined sugar. Nearly 70% of the refined sugar distributed is now shipped to food processors. A small number of sellers of refined sugar, operating in a highly competitive atmosphere, have through individual research tailored their marketing to the exacting and diversified requirements of the food processors and the standardized grocery trade. The application of individual research to clearly defined consumer demands has led to a highly efficient marketing system.

Although the distribution phase of marketing refined sugar may be quite competitive and efficient, there are problems in the earlier stages of sugarbeet marketing. Improved techniques and equipment are needed for handling, storing, and transporting sugarbeets more economically. Storage and labor are important marketing costs. For both items the range is fairly wide between the most and the least efficient operations. The influence of transportation rates on marketing costs and the impact of nonsugar sweeteners on demand for sugar need to be kept current.

OBJECTIVE: Provide up-to-date information based upon analyses of market factors to improve marketing efficiency.

RESEARCH APPROACHES:

A. Determine the relationship of equipment design, plant layout, handling methods, and storage on product quality and marketing costs.

B. Develop new or improved equipment and facilities for handling, storing, and transporting products to improve quality and reduce marketing costs.

C. Evaluate the overall organization and performance of sugarbeet markets, including studies of prices, marketing costs, margins, competition, market information, practices, and services.

# III. SUGARCANE RESEARCH GOALS AND PROBLEM AREAS

# RPA 207 CONTROL OF SUGARCANE INSECTS

## 207-A Insect Biology

SITUATION: Several insect species annually cause extensive losses to the domestic sugarcane industry. The sugarcane borer, wireworm, yellow aphid, and sugarcane grubs are important pests on the mainland and in Puerto Rico. The Hawaiian sugarcane borer and sugarcane leafhopper are very troublesome in Hawaii. Insects are also vectors in transmitting important diseases. Information about the biology, behavior, development, host range and population dynamics of sugarcane insects is a basic need. Insect pests, parasites, predators, and vector relationships must be understood as the basis for developing new effective, safe control measures.

OBJECTIVE: Determine life histories, distribution, occurrence, abundance, habits, nutritional requirements, and other biologic, physiologic, and ecologic characteristics of sugarcane insects as a basis for improved methods of control.

RESEARCH APPROACHES:

A. Determine the nutritional requirements of important insect species, their parasites, and predators for developing artifical diets for mass rearing.

B. Obtain basic information on population dynamics, mating behavior, sex attractants, migration habits, and other biological activities useful for suppression, eradication and/or control studies. Develop life cycles for insects in different ecological areas.

C. Study sterilization with radiation or chemosterilants using established bioradiation techniques. Determine if large-scale release of sterile males will provide control in extensive areas.

D. Evaluate sex attractants and electromagnetic radiation.

E. Evaluate natural and synthetic hormones that affect development and reproduction.

F. Study the taxonomy of insects, parasites, and predators. Develop tests to identify and classify physiologic races.

G. Determine the economic injury threshold of important species by studying the effect on various growth stages, yield, and quality.

H. Determine the host-range of insect species that serve as vectors for diseases.

## 207-B Resistant Varieties and Cultural Practices

SITUATION: Opposition to the use of pesticides is becoming more intense. Undesirable residues are a problem. Some materials harm wildlife. They upset the balance of organisms that reduce insect pests naturally. Some insects are resistant to insecticides. Insect resistant varieties are an effective, economical, and safe way to control troublesome species. Some progress has been made. Varieties less susceptible to the sugarcane borer are available. However, the search to find new sources of insect resistant germplasm must be expanded. Research to utilize these new sources for developing better insect resistant varieties is essential for control of pests. Modification of crop culture may also prevent or lessen insect damage. Such practices may include changes in time or method of planting, tillage, harvesting, crop rotation, crop refuse, destruction, or fertilizer application. Cultural practices are a useful technique to minimizing injury.

OBJECTIVE: Control insect losses by developing resistant varieties and cultural practices that will minimize injury.

RESEARCH APPROACHES:

A. Collect, evaluate and characterize germplasm for insect resistance.

B. Transfer resistant germplasm to adapted varieties. Attempt to develop multiple-resistant varieties by combining genes for resistance to different insects.

C. Conduct basic chemical, physiologic, and genetic studies to determine the nature of the resistance.

D. Determine the presence and abundance of physiologic races.

E. Determine the effect of resistant varieties on insect pest, parasite, and predator populations in commercial plantings.

F. Study the effect of various crop rotation, tillage, and crop residue management practices on the insect population.

G. Identify changes in insect incidence due to acceptance of new management practices.

## 207-C Biologic Methods

SITUATION: Parasites, predators, and other biologic control agents play a major role in reducing insect populations. Producers in Hawaii, Puerto Rico, and to some extent in Florida, depend largely on these agents. Chemicals, on the other hand, are used in Louisiana and parts of Florida to complement natural control systems. Many insect pests in the United States are not endemic. They were introduced from foreign countries without the parasities or predators that attack them in their native land. These control agents must be found and established in this country. Techniques for mass production and release of some insect parasites are well developed. This method of control is being tested against the sugarcane borer in Louisiana using the parasite *Trichogramma*. Naturally occurring diseases may be effective in terminating an extensive insect outbreak. We must determine if such insect pathogens can be propagated and disseminated to control insects.

OBJECTIVE: To extend the use of parasites, predators, and insect pathogens as a control measure.

RESEARCH APPROACHES:

A. Search for parasites, predators, and pathogens of sugarcane insects in their native home. Propagate, and disseminate these agents in the area where the host insect occurs in domestic production areas.

B. Evaluate native and introduced parasites, predators, and diseases for the control of major sugarcane pests.

C. Develop techniques for mass production and release of parasites, predators, and insect pathogens and evaluate these organisms as a practical control measure.

207-D Chemical Methods

SITUATION: Insecticides are effective in sugarcane when biological control and other methods fail. Insecticides will continue to be the first line of defense against some insect pests such as wireworms. However, several insects have become resistant to insecticides. Furthermore, some insecticides reduce populations of beneficial insects and wildlife. New materials effective against specific insect species and harmless against man, animals, and other useful organisms, are urgently needed. Selective biodegradable insecticides that do not accumulate in plant and animal tissues, and magnify through food chains, must be developed. Since residue problems arise from insecticide drift to non-treated areas there is need for improved non-drift formulations and application equipment.

OBJECTIVE: Develop safe, effective, economic chemical control methods that leave no objectionable residues, are harmless to ecologic systems, and cause a minimum of soil and water pollution.

RESEARCH APPROACHES :

A. Evaluate new insecticides for control of important species of insects that attack sugarcane.

B. Test different insecticide formulations, rates, and time of application, using both ground and aerial equipment.

C. Evaluate the effect of insecticides on beneficial insects and wildlife.

D. Determine insecticide residues in the plant and soil after application in the cane and in the bagasse.

# RPA 208 CONTROL OF SUGARCANE DISEASES

## 208-A Genetics and Breeding

SITUATION: Sugarcane diseases are an ever-present production hazard. Epiphytotics have been so severe that industries in Puerto Rico and Louisiana, for example, were brought to the point of collapse. Resistant varieties are the most effective means of control. Several commercial varieties have improved levels of disease resistance to important pathogens in our domestic production areas. This situation, however, changes as infectious agents become altered. Strain H of mosaic, a current threat to Louisiana producers, demonstrates this principle. The base of resistance of current varieties is too narrow. It does not provide adequate protection from changes of existing pathogens. It provides questionable resistance to certain foreign pathogens that are a constant threat. Development of new varieties with vastly improved mechanisms for resistance will require: new genetic techniques; new sources of broad-spectrum resistance or immunity; knowledge about mode of inheritance; and more complete knowledge about the range of parasitism of pathogens.

OBJECTIVE: Identify new sources of disease resistance to provide broad-spectrum protection and incorporate this germ plasm in new varieties of sugarcane for different ecological systems.

RESEARCH APPROACHES:

A. Study the variability of sugarcane pathogens in relation to existing germ plasm governing resistance to diseases.

B. Screen selected clones in the world collection of sugarcane for resistance to strains of selected pathogens.

C. Study the mode of inheritance of resistance in important sources of broad-spectrum germ plasm.

D. Initiate studies on new genetic procedures to expand the base of crosses. Develop new procedures to manipulate characters governed by multiple genes.

E. Conduct breeding programs using improved germ plasm and genetic procedures to produce new varieties for commercial culture.

F. Inoculate all varieties being considered for commercial release with important pathogens and rate them for resistance.

208-B Soil Pathogens

SITUATION: Sugarcane, a perennial plant, frequently is grown without rotation in large areas for extended periods. This encourages development of parasitic soil microflora. There is reason to conjecture that such pathogens contribute to yield decline of varieties. *Pythium* sp. dèvelop strains selective for particular varieties. Decaying sugarcane roots and trash add tons of organic matter and unidentified toxic compounds to the soil. The effect of decaying roots and trash on organic composition of the soil may alter host-parasite relationships. Our knowledge of soil pathogens affecting sugarcane is inadequate.

OBJECTIVE: Determine the role of the soil microflora in yield losses, and particularly long range yield decline in sugarcane varieties.

RESEARCH APPROACHES:

A. Identify organisms in soils cropped continuously to specific sugarcane varieties in comparison with normal cropping.

B. By appropriate techniques, determine any increase in prevalence of virulent races of pathogens.

C. Study relation of the pathogens identified to yield losses, particularly long range yield decline trends.

## 208-C Mosaic Epidemiology

SITUATION: Sugarcane mosaic is a major virus disease that deserves intensive study. It is spread by aphids; the disease severity, therefore, is influenced by factors that affect vector populations. The mechanisms influencing the rate of spread are not well understood. Vector populations are important. They are influenced by the kind and prevalence of preferred weed host plants. Parasites also govern vector populations. Varieties have an effect on the vectors. Some are not attractive to aphids. Others may be suitable hosts but carry high levels of resistance thereby affecting the transmission cycle. Mosaic will be combatted more effectively as we understand its epidemiology.

OBJECTIVE: To determine the biological and environmental factors influencing spread of mosaic.

RESEARCH APPROACHES:

A. Trap aerial insects over fields with known histories of high and low rates of spread. Identify known mosaic vectors and other suspect insects. Determine their relative importance and prevalence.

B. Determine the rate of mosaic spread in selected sugarcane varieties planted in the same location. Correlate these data with vector populations.

C. Determine the kind, prevalence, and location of weeds that serve as hosts for vectors. Study the effect of weed control on vector populations and spread of mosaic.

208-D Improved Techniques for Identifying Presence of Pathogens in Sugarcane Plants

SITUATION: Reliable techniques for identifying certain diseases in sugarcane plants are lacking; i.e., RSD, chlorotic streak, leaf scald. This is a handicap to research, such as determining efficacy of heat treatments, and transmission. Much time is lost in the time-consuming methods of identification now available, which are often imprecise. Breeding for resistance to RSD is virtually impossible because of lack of a suitable technique for screening large progenies for resistance. Improved techniques for virus detection might lead to the identification of as yet unrecognized viruses which may be involved in yield decline of sugarcane varieties.

OBJECTIVE: Develop more precise and rapid methods of disease identification in sugarcane plants.

RESEARCH APPROACHES: Investigate improved identification techniques by molecular separation, differential centrifugation, density gradient electrophoresis and serology.

## 208-E Interrelationships Among Sugarcane Pathogens, Varieties, and Environmental Conditions

SITUATION: Numerous plant pathogens are known to attack sugarcane. Estimates of yield reductions have been made for various diseases, but because of the interactions of pathogen, variety and cultural conditions, and of the combinations of pathogens which attack this perennial crop, disease losses may range from minor to the destruction of the crop. The interrelationships among pathogens, varieties and growing conditions as they determine the severity of disease are not well understood. Information concerning the factors that affect disease losses is essential for an efficient control program.

OBJECTIVE: Gain a more thorough understanding of the factors affecting disease expression in sugarcane.

RESEARCH APPROACHES:

A. Identify pathogens and determine environmental factors favoring their development.

B. Study genetic and environmental variability of pathogens.

C. Study interrelationships of two or more pathogens as affected by the variety of sugarcane, by rotation of other crops with sugarcane, and by environmental conditions.

D. Develop effective inoculation techniques to facilitate studies of injury and control methods.

E. Study the mechanisms whereby an infected plant may avoid damage by a pathogen.

208-F Disease-free Propagating Material

SITUATION: Asexual propagation of sugarcane creates a problem of disease accumulation in propagating material. Viruses are particularly important. A differential thermal death point exists between the host plant and some pathogens. This fact is exploited commercially. Large-scale treating plants use hot air or water to treat big lots of seed pieces. The treatments are not adequate. Some pathogens such as the ratoon stunting disease are not completely erradicated. Mosaic is unaffected. Seed piece viability is reduced. The treatments are cumbersome and costly. Control of sugarcane diseases would benefit from improved techniques.

OBJECTIVE: Study factors affecting viability of systemic pathogens in sugarcane seed pieces.

RESEARCH APPROACHES:

A. Conduct basic studies on RSD and mosaic. Study pathogens in seed pieces to determine their concentration, location, and interrelationships with host tissues in relation to a wide range of environmental factors.

B. Develop new concepts to kill virus pathogens in host tissue such as high frequency sound, radiation, pressure, and chemicals.

C. Study the physiologic state of host tissue as it relates to preconditioning of cane to be used for propagation.

208-G Foreign Diseases

SITUATION: Several major sugarcane diseases of the world do not occur in domestic production areas. The danger of introducing these diseases, their host plants or biological vectors increases yearly as air travel expands. Some diseases remain latent during quarantine. Symptoms do not manifest themselves until a clone has been planted in a commercial cane area. Rigid quarantine procedures for new material in all domestic areas is necessary. Reaction of our varieties to diseases in other countries should be determined.

OBJECTIVE: Prevent introduction of foreign sugarcane diseases, their host plants or biological vectors into the United States and determine disease reaction of U. S. varieties in other countries.

RESEARCH APPROACHES:

A. Initiate basic studies on factors governing symptom expression of diseases under a wide range of environmental conditions.

B. Study new techniques for identification of important foreign pathogens; devise new procedures to insure freedom from pathogens of introduced clones.

C. Test U. S. varieties and unreleased material for their reaction to such diseases as: smut, downy mildew, leaf scald, gummosis, Fiji, grassy shoot, and white leaf.

## 208-H Nematode Diseases

SITUATION: Nematodes are known to cause diseases of sugarcane in most parts of the world. Many different species are associated with sugarcane, and the pathogenicity of about 8 species has been determined in Louisiana, Florida, and Hawaii. Nematodes are known to cause injury to sugarcane roots by the mechanical damage they inflict with a stilleto-like mouthpart and by toxin secretions for food digestion. Moreover, they provide avenues for bacteria and fungi and are suspected of vectoring viruses. The root-knot nematode causes galls or swellings on the roots. Since large populations build up on the stubble, they are suspected to play a major part in stubble deterioration. Emphasis on control has been the application of nematicidal chemicals. Florida and Louisiana have reported more than 25% yield increases with the newer type organophosphate and carbamate nematicides. Very little is known about varietal resistance to different species of plant-parasitic nematodes. Biological control has been largely a failure.

OBJECTIVE: Increase the life of the sugarcane stubble and make it possible to grow a crop year after year without fallow plowing and crop rotation by the safe and economic control of nematodes and nematode-fungal complexes.

RESEARCH APPROACHES:

A. Investigate the occurrence, population dynamics, and host-parasite relations of nematodes associated with sugarcane.

B. Determine the relationships between nematodes, fungi, bacteria, and viruses in their role in sugarcane disease and stubble deterioration.

C. Evaluate new organophosphate and carbamate nematicides for nematode control and their effects on tonnage, sucrose yields, and crop residues.

D. Select resistant varieties for nematode control and investigate the effect of the most promising nematicides on these varieties.

E. Study the compatibility of nematicides with herbicides, fungicides, and insecticides in one combined field application.

F. Study nematode resistance to chemicals and the existence of different pathogenic races on sugarcane.

G. Elucidate the possibility of biological control with the parasitic *Catenaria* fungus.

# RPA 209 CONTROL OF SUGARCANE WEEDS AND OTHER HAZARDS

## 209-A Weed Life-Cycles

SITUATION: The wide range of soil and climatic conditions of the domestic sugarcane-producing areas is characterized by a variable weed flora. Some of these are particularly troublesome. The anatomy, morphology and physiology of most weed species have received little attention. Knowledge of the life cycles of annual and perennial weeds is necessary to determine growth stages most susceptible to cultural or chemical control practices. Total destruction of weed seeds in the soil, whether dormant or not, would permit rapid dimunition of populations; a means to quantitatively break weed seed dormancy is also needed. Weed populations are plastic and respond to natural and applied stress, both cultural and chemical. Certain weeds in the Louisiana sugarcane area could be classed as highly resistant to practically immune to chlorophenoxy herbicides. They are becoming major pests. A broad range of weed control measures is basic for profitable production of sugarcane.

OBJECTIVE: Determine the life cycles of major annual and perennial sugarcane weed infestants to find stages of growth where control measures are most effective.

RESEARCH APPROACHES:

A. Prepare a "census" list of major weed infestants, including distribution and concentration of population and seed source.

B. Determine growth cycles of weeds.

C. Establish and evaluate the anatomic, morphologic, and physiologic characters related to cultural and chemical control programs.

D. Study the characteristics, including dormancy, of the propagules of the important weeds, to determine the natural factors influencing dormancy and development. Evaluate means of influencing these characteristics and factors.

E. Determine the tolerance of weed species to chlorophenoxy herbicides, and other formulations.

F. Evaluate the influence of cultural and chemical practices on weed successions.

## 209-B Weed Competition

SITUATION: Domestic sugarcane varieties are comprised of diverse genetic combinations which are reflected in plant habit and growth characteristics. They respond in a fairly predictable fashion to primary stimuli, such as moisture, temperature, and photoperiod. The growth of weed populations, however, does not necessarily coincide with cane growth, even in the tropics where sugarcane is native. Individual species of weeds may commence development late in the crop when practical means of weed control are precluded. Little is known of the extent and importance of specific weed competition in this crop or of the competitive ability of sugarcane varieties.

OBJECTIVE: Determine the competitive ability of diverse sugarcane types and examine the influence of time and intensity of weed competition.

RESEARCH APPROACHES:

A. Study growth cycles of major weed infestants in relation to the competition of sugarcane.

B. Determine relationship between sugarcane growth habit and agronomic response under competition with pure and mixed weed populations during natural crop and weed seasons for plant and ratoon crops.

C. Determine the weed-free period necessary for maximum sugarcane performance.

D. Determine sugarcane plant characters that enhance competition.

## 209-C Mechanisms of Herbicide Action

SITUATION: Herbicides for all crops are developed by large-scale, systematic evaluation of chemicals. This is essentially an industry activity. Improved formulations are needed for sugarcane. Chemicals useful in one area are not accpetable in another because of parochial differences in soil, climate, cropping practices and economics. The reliability of pre-emergence herbicides is not adequate, especially under marginal climatic circumstances. Postemergence herbicides, widely used in sugarcane, may perform erratically or may injure the crop largely in relation to dosage, timing and manner of application. Knowledge of the mechanisms of herbicide action would assist in the search for more effective chemicals and more effective use of available herbicides.

OBJECTIVE: Establish mechanisms of herbicides action and to develop more effective chemicals.

RESEARCH APPROACHES:

A. Evaluate the effects of herbicides on metabolic systems in sugarcane and weed plants.

B. Develop and test theories of mechanisms of herbicide action and selectivity.

C. Develop models of potentially effective herbicides.

209-D Herbicide Specificity, Selectivity and Interaction with Other Chemicals

SITUATION: The domestic sugarcane crop is grown under diverse edaphic and climatic conditions in competition with a variable weed flora. Herbicides developed during the past 2 decades offer a practical, temporary practice for combatting weeds. The procedures, however, are far from optimum. Under pressure of cultural and chemical weed control practices, plastic weed populations have become altered in kind and density. Rates of herbicides necessary for effective control of specific weeds vary under the different production conditions. Some herbicides have not been evaluated critically against some weed species in specific production areas nor for crop varietal tolerance. In modern agriculture, it is customary to utilize an array of pest control chemicals for effective and economical production. Fungicides, insecticides and nematicides may be used in addition to herbicides. The influence and interaction of these chemicals has not been evaluated carefully.

OBJECTIVE: Determine the practical minimum effective dosage and toxic response dosage of herbicides to sugarcane and to its weed infestants. Evaluate interactions between herbicides and other crop protection chemicals.

RESEARCH APPROACHES:

A. Determine minimum rate of new and existing sugarcane herbicides alone and in combination necessary for field control of specific weeds under soil and foliar application.

B. Determine the interrelationships of herbicide, fungicide, insecticide and nematicide programs or combinations on pest control and on sugarcane.

C. Develop pest control chemical programs conducive to effective broad spectrum weed control and to improved crop tolerance.

## 209-E Chemical and Cultural Combinations

SITUATION: The factors affecting weed control differ narrowly or widely from farm to farm within an area as well as between areas. The weed population of a specific sugarcane planting reflects the grower's success in effectively combining various control practices. Johnsongrass stands in Louisiana sugarcane fields are an example of this practical fact of weed control. The general level of weed control will be improved as combination practices are simplified. More effective weed control will be possible as we understand the response of specific weeds to cultural and chemical practices.

OBJECTIVE: Determine principles and practices to provide the most adequate system of chemical and non-chemical control of specific weeds in sugarcane.

RESEARCH APPROACHES:

A. Study the effect of non-chemical practices on specific weed populations: biological, climatic (flooding), cultural and rotational.

B. Evaluate and develop combinations of cultural and rotational practices with herbicides for control of specific weed species.

## 209-F Herbicide Application Techniques

SITUATION: Effective, and potentially useful, herbicides are not used in some crops because suitable application techniques are lacking. Some chemicals volatilize readily. Others require high soil moisture for activity. A third group may damage the crop on contact. Ratooning, topping and trash practices influence the choice and effectiveness of herbicides. The relatively "non-selective" herbicides may be useful with directional application equipment. Volatile chemicals may be amenable to soil incorporation or other application methods. Herbicide efficiency is improved by appropriate application techniques.

OBJECTIVE: Evaluate chemical application techniques and develop methods, including equipment, to improve weed control programs.

RESEARCH APPROACHES:

A. Determine the most effective and efficient methods of applying herbicides when needed during the crop production cycle.

B. Develop methods of avoiding herbicide losses at application and of minimizing harzards to adjacent crops.

C. Develop and evaluate equipment for: 1) soil incorporation of herbicides, 2) broadcasting them, and 3) directional application. of herbicides prior to or during crop growth.

## 209-G Crop and Soil Herbicide Residues

SITUATION: The degradation rate of herbicide residues in the soil is mediated by a number of natural factors. Carryover of residues detrimental to crops other than sugarcane is possible where rotations are practiced. Herbicides may enter the sugarcane plant via soil uptake or via foliar exposure to the chemical sprays. Degradation or persistence of residues in the sugarcane plant are related largely to the specific chemical and the application dosage and timing. Potential crop injury and environmental contamination can be avoided by knowledge of the fate of herbicides, their metabolites and residues in soil and plant.

OBJECTIVE: Establish the fate of sugarcane herbicides in the crop and soil, and the potential hazard of these residues to sugarcane or succeeding crops.

RESEARCH APPROACHES:

A. Determine herbicide residue levels in sugarcane and soil under different, but specific, application and environmental conditions.

B. Determine presence and toxicity of herbicide residue metabolites under the above conditions.

## 209-H Control of Rodent Pests in Sugarcane Fields

SITUATION: Rodents, mostly rats, cause damage to the crop in all domestic sugarcane-producing areas. Severity of damage and resulting loss vary greatly from area to area, from year to year and even from field to field. The problem is long standing and a continuing one. Control methods now available are unsatisfactory because they are not effective and because they are costly, especially in terms of labor.

Research is needed on methods of surveying for rat infestations and for correlating infestation with damage. Basic research is needed on the ecology of rodents in cane fields in order to concentrate control methods research on those species that do the most damage.

Research is needed to develop effective, economical methods for controlling rats in sugarcane fields as well as in areas adjacent to sugarcane fields that may provide sources of infestation.

OBJECTIVE: Develop new and improved methods of controlling rodents in sugarcane fields to prevent loss of cane and sugar.

RESEARCH APPROACHES:

A. Expand knowledge about the ecology of rats, especially those that are in and adjacent to sugarcane fields. This should include (a) using census technics for population studies; (b) developing methods to evaluate damage and loss, (c) studying reproductive cycles, (d) studying movements within and into and out of cane fields, and (e) investigating interaction between species.

B. Develop and evaluate new chemical methods for controlling rodents. This may require synthesis of new compounds but will certainly require laboratory screening and then field testing of all likely control agents. This approach should not be limited to toxicants but should include antifertility agents, repellents and any other material that may offer prospect of achieving the desired control.

C. In order for any toxicant, antifertility or other physiological agent to work, it must be ingested by the animal. Therefore, investigation of baits and attractants is basic to evaluation of chemical controls.

D. Study the effects of agricultural practices on rat ecology and on damage to sugarcane. This would include research on effects of tillage practices, fertilization, weed control practices, and of choice of sugarcane variety on rat populations and on susceptibility of cane damage by rats.

E. The possibility of biological control should not be overlooked, although past experience with parasites and predators for control of animal pests has not been encouraging.

## RPA 307 BIOLOGICAL EFFICIENCY

### 307-A Genetics and Breeding

SITUATION: Improved varieties have greatly increased the yield of sugar from sugarcane. Further improvement will require substantial additions to our basic knowledge about sugarcane genetics. Population genetics, for example, is one of the significant fields of study. The genetic analysis of plant characteristics, such as gross morphology and physiological responses is also essential. These include studies of genetic and environmental interactions to improve selection procedures. Physiological, biochemical, and tissue and cell culture studies must be utilized in genetic analysis. New mathematical formulae for studies of population genetics must be developed. Those used for the analysis of diploid seed propagated plants are not directly adaptable to highly heterozygous and polyploid asexually propagated plants such as sugarcane. High capacity computers are a valuable tool for basic studies on inheritance. The 5 to 10 year breeding and selection cycle required for new sugarcane varieties must be reduced.

OBJECTIVE: Develop improved sugarcane breeding methods that will result in improved varieties in a shorter period of time.

RESEARCH APPROACHES:

A. Expand the diversity of germplasm through exploration of the centers of origin of *Saccharum* and related genera.

B. Screen new sources of germplasm for disease and pest resistance, and more efficient physiological and photosynthetic variants. Utilize such material in breeding programs.

C. Investigate the use of tissue and cell cultures in making directed genetic changes at the cellular level through induced mutations, manipulation of the chromosome number, and transformation, with subsequent differentiation of plants from the treated cells.

D. Investigate the extent to which sugarcane can be bred to improve its efficiency in the utilization of solar energy, carbon dioxide, water and nutrients in the production of both cane and sugar.

E. Develop genetic combinations to provide effective resistance to a wide range of diseases and other pests and to their races.

F. Study the genetic basis for the contributions of the components of sugarcane yield, emphasizing mainly sucrose content, number of stalks, length of stalk and size of stalk in a given amount of time.

G. Develop mathematical formulae and computer programs for information retrieval and analysis of basic genetic and population genetic studies.

H. Investigate methods of breeding and selection to reduce the length of the breeding cycle.

## 307-B Nutrition, Fertilization and Soil Amendments

SITUATION: Maximum yields of sugar from cane depend on the supply of essential and accessory elements. Nutritional requirements are such that these materials must be adequate in supply and in proper balance. Insufficient or excessive amounts of some elements can limit production. Fertilizers containing N-P-K and other elements are used routinely. The amounts, however, must be adjusted to varietal differences that occur. This may include differential response to kinds of fertilizers. The trend toward use of high-analysis fertilizers is altering nutritional concepts. They induce, for example, the depletion of available forms of certain nutrients. Fertilization programs would be vastly improved if we could anticipate deficiencies and correct them before they occur. A better understanding is needed of elements that depress sugarcane growth. The maximum yield potential of sugarcane varieties will be achieved only as we know about the precise nutritional requirements, of specific varieties, in different stages of growth, in different soil and climate environments.

OBJECTIVE: Develop fertilizer and soil amendment programs for optimum nutrition.

RESEARCH APPROACHES:

A. Develop fast, precise methods to measure the nutrient demand of different varieties in different environments.

B. Develop inexpensive, small-scale methods that will determine application rates of fertilizers for different soil types and environmental conditions.

C. Determine adverse effects of some elements in soils or fertilizers on crop growth. Study the mode of action as a basis to develop methods to minimize or eliminate the problem.

## 307-C Crop Management

SITUATION: Generally, a "best" starting date for a fixed cropping period is established for different growing areas and this schedule is adhered to. It was found in Hawaii that the common 24-month cropping period in some instances is too long for a maximum return of sugar, due to crop deterioration. Conversely, in other instances, the common 24-month cropping period is too short. Since, in such situations, cropping periods other than 24 months are not practical because the best starting time is disrupted, crop management practices need to be developed to allow prime crop condition and maximum sugar production to occur at 24 months. Similar research should be initiated for a 12-month cropping period.

OBJECTIVE: Develop methods to achieve prime crop condition for maximum sugar yield at 12 and 24 months' crop age.

RESEARCH APPROACHES:

A. Develop methods to characterize areas with respect to interactions of variety and location in relation to fixed age cropping.

B. Determine effects of timing and amounts of nitrogen and irrigation under a given climatic situation on growth characteristics, cane quality, and sugar yield at harvest.

C. Develop the use of growth regulators to aid in bringing a crop to maturity at the specified age.

## 307-D Plant and Environment Interaction

SITUATION: Sugarcane varieties vary in their reaction to a given set of environmental conditions. Some grow vigorously with extremely high solar radiation but do poorly with decreased light. Others produce surprisingly well under low radiation and some do well under both conditions. This same situation prevails for interactions with other environmental factors, particularly water, temperature, spacing, and crop age. The biological efficiency of sugarcane would be increased if one could easily and quickly recognize the interaction of the above factors with specific genotypes. Such information would be of paramount importance in selecting varieties for maximum performance. Growers could anticipate the action required for maximum performance when non-cyclic or unanticipated changes affect the crop.

OBJECTIVE: Determine methods to evaluate interaction of varieties and environment.

RESEARCH APPROACHES:

A. Develop tests to evaluate varietal interactions with differing environments. Develop methods for selection. These studies should include spacing, age, solar radiation, water, and temperature.

B. Determine physiologic and biochemical characteristics connected with responses to the environment that can be controlled.

C. Study anatomical structure and growth as it relates to spacing, aging, and senescence. Determine the interaction of these factors with the environment and eventual effect on yield and quality.

D. Study the physiology of temperature reactions, drought and excess water responses, and oxygen relationships.

## 307-E Plant Metabolism and Growth

SITUATION: Substantial advances have been made in removing obstacles to near-optimum growth of sugarcane. This is particularly so of weed control, water supply, fertilizers, plowing and other cultural practices. Future gains in these fields will be made but will be progressively smaller than those obtained in the past. New approaches, however, are now available to substantially increase yields of sugar. These techniques will control plant functions by directing the metabolism and growth of the sugarcane plant to fit the needs of the grower. There are many stages in the development of a cane plant where directional channeling of its metabolism and/or growth habits might be controlled by chemical or other means. Some of these are germination, early growth, tillering, photosynthesis, translocation, flowering, stalk size, ripening, and leaf dessication. Examples of success in this approach include the use of gibberellins for stalk elongation, CMU and diquat for tassel control, and diquat and paraquat for leaf dessication.

OBJECTIVE: Understand growth and metabolic processes for their control through chemical and other means for increased yields and/or quality.

RESEARCH APPROACHES:

A. Study metabolic pathways to determine (a) if they are proceeding in a normal pattern and at a normal rate, (b) if there are metabolic blocks, and (c) which step(s) in a pathway might be modified to increase yields.

B. Study physiological processes to determine control mechanisms which might, in turn, be chemically managed to result in yield increases.

C. Develop tests to evaluate the effects of chemicals on the various metabolic and growth processes.

D. Screen chemicals to determine those which affect the various metabolic and growth processes.

E. Determine proper procedures and adjuvants for field testing of active compounds.

F. Determine the mechanism of action of effective compounds to select specifically active chemicals rather than go through empirical screening.

# RPA 308 MECHANIZATION

## 308-A Mechanization of Production

SITUATION: The conditions, problems, and degree of sugarcane mechanization vary widely in Louisiana, Florida, Puerto Rico, and Hawaii. Terrain and soil conditions differ from the relatively flat mucklands of Florida to very steep, rocky land in Hawaii. Rainfall varies from 20 to 200 inches per year. Due primarily to age of crop, yields vary from 35 to 135 tons cane per acre. The higher yielding cane is always recumbent at harvest, as is much of the lower yielding cane. A hurricane may level upright cane at any time. Trash in the form of dry and green leaves, tops, soil, and rocks cause difficulties in harvesting, cleaning, and milling; if the cane is cleaned before processing by washing with water, high sugar losses result. Freezing weather in Louisiana and Florida before harvest may cause the crop to spoil, thus causing special milling problems. Air and water pollution regulations will affect burning and waste disposal practices. Although the extent of mechanization varies considerably by area, a common high priority problem exists. For recumbent cane in each area, there is an urgent need for an integrated and mechanized harvesting, cleaning, and delivery system that will not be harmful to our environment. Of considerably less priority is the further mechanization of other field operations.

OBJECTIVE: Develop principles for mechanized harvesting, cleaning, and handling of recumbent, unburned cane that will minimize sugar loss and yield a product acceptable for milling without soil destruction and field damage. Develop principles for mechanization of other field operations as required for a changing technology.

RESEARCH APPROACHES:

A. Develop principles for harvesting lodged and recumbent sugarcane with maximum topping and cleaning in the field.

B. Develop principles of cane dry cleaning, with emphasis on top removal and including rock removal.

C. Investigate various ways of handling cane as part of an integrated approach to harvesting, cleaning and transporting.

D. As indicated by local conditions and needs, assist in the development of other field machines--planters, tilling machinery, etc.

E. Develop application machinery for chemicals.

F. Assist in the improvement of drainage and irrigation systems.

G. Assist in the development and improvement of cultural practices affecting plant and ratoon stands, including investigation of new approaches to producing, planting, and replanting seed cane.

# RPA 309 SYSTEMS ANALYSIS

## 309-A Systems Analysis for Production

SITUATION: Production of sugar from sugarcane is complex. A large-scale agricultural operation produces a huge tonnage of a bulky perishable crop. After harvest, quick transfer to large factories for immediate processing is essential. The logistics of this activity are complicated. There are problems associated with the seasonal nature of production. Many growers are involved and they must be mobilized along with other labor and machinery into an effective harvest force. An efficient industry must choose among many variables for effective management. Some of them are: variety of sugarcane; planting and harvest time; timing, type, and quantity of nutrients; moisture requirements; herbicide and pesticide treatments; age of crop; number of ratoons; capacity, number and location of processing plants; and field mechanization requirements, including the type and capacity of machinery. Specific choices must be made for particular areas among a long list of alternative methods of production. Models for management utilizing mathematical principles are an urgently needed management tool. They must be capable of considering an entire system. Restraints on the industry, for example, are imposed by the availability of land, capital, labor, and technology. Many inputs into the production cycle have parameters, both controlled and uncontrolled, that determine profitability. Mathematical models must be capable of considering the economic alternative of each part of a system as it relates to the whole. We do not have such tools at this time.

OBJECTIVE: Develop management systems that provide maximum profit from the total system regardless of input variations.

RESEARCH APPROACHES:

A. Analyze resource utilization at the farm level as it is subject to the constraints in climate, land, labor, and capital.

B. Develop models to accommodate diverse conditions of a region and for different regions. To determine the optimum combination of relevant inputs.

C. Develop methods to obtain quantitative input-output data describing production systems. These will include field, plant, environment, mill, and any other relevant condition. Some data will be relatively static subject to occasional step changes, such as field size, field layout or mill capacity. Other data may be subject to continuous change, for example, crop growth and machine output. Control systems must be developed.

D. Develop means to control the operation of actual or proposed systems. For example, (1) the allocation of areas to be harvested so that cane transporation costs will be minimized, and (2) method of continuous crop logging and weather recording as a basis for program control, nutrition, moisture, and maturation.

E. Simulate and analyze existing and proposed systems to determine the conditions for maximum benefits and compare with alternative systems.

## RPA 405 CONSUMER ACCEPTABILITY

### 405-A Production of Sugarcane with Improved Quality

SITUATION: Quality of sugarcane is a most important factor in determining profit or loss for the industry. The balance of sucrose content and amount and nature of soluble solids is the keystone to economic successful extraction and crystallization. Quality is variable and dependent on many factors. These include: variety, climate, moisture, nutrient levels, handling procedures and many others. The relatively quick loss of quality after harvest reduces eventual "sugar-in-the-bag." The extreme susceptibility of quality to freeze injury and burning complicates processing. The deleterious physiologic changes that take place in sugarcane after harvest are poorly understood.

OBJECTIVE: Develop varieties and cultural practices that will improve quality and lengthen its retention after harvest.

RESEARCH APPROACHES:

A. Identify genetic characters responsible for quality. Determine how to manipulate them by breeding.

B. Conduct basic physiologic-agronomic studies directed to the control of quality and ripening.

C. Study the factors affecting sucrose formation, translocation, and storage in terms of cultural and handling practices.

D. Initiate comprehensive research on freeze damage as it relates to quality deterioration.

# RPA 406 FOOD PRODUCTS

## 406-A Sucrose Extraction Efficiency

SITUATION: The goal of good milling practices is to extract 95% or more of the sucrose. Even under optimum conditions, extraction by crushing seldom recovers more than 90% in Louisiana; and 92% in Florida. Extraction by crushing may recover higher percentages of sucrose in Hawaiian and Puerto Rican mills except under adverse conditions. Even so this process uniformly does not recover as much sucrose as extraction by diffusion. The latter process may recover as much as 97%. Hence, technology exists for increasing sucrose extraction efficiency. However, many raw sugar factories have not been converted in part or completely to a diffusion process, because of large investments in milling equipment. A combination milling-diffusion facility might serve a useful purpose, because some of the milling equipment on hand could be used. Moreover, a combination process should increase extraction efficiency by at least 1% to 3%. Research is needed that will lead to the selection of more economic and more efficient extraction processes.

OBJECTIVE: Increase the sucrose extraction efficiencies of raw sugar factories.

RESEARCH APPROACHES:

A. Determine the relative sucrose extraction efficiencies for crusher and diffusion processes and combinations thereof.

B. Determine the compositional differences of the juices obtained under "A" and relate these to factory performance.

C. Evaluate chemicals for preventing the inversion of sucrose by enzymes and microorganisms during extraction.

D. Evaluate physical methods such as ultrasonics as aids to making sucrose in cane more readily available for diffusion extraction.

E. Relate cane quality factors to sucrose extraction efficiency.

406-B Higher Yields in Purer Raw Sugars

SITUATION: There are continuing needs in the sugarcane industry to increase the yields and purity of raw sugar. Coupled with these is the desirability of reducing operating costs. Ten to 15% of the sucrose contained in the extracted juice may go into the molasses and press cake or disappear in other undetermined ways. Purity is also becoming an increasingly important factor in the marketing of raw sugar. Refiners are writing refining qualities into their raw sugar specifications for contract purchases. Variations from a standard in such characteristics as grain size, ash content, moisture, filterability or color may result in a price penalty. Penalties can be severe under adverse crop conditions, and can mean the difference between profit and loss. High trash contents, soil, prolonged storage of cut cane, freezing, and excessive pest infestations contribute to the impurity problem and cause variations in factory performance because of changing quality and quantity of non-sugar constituents. Other factors are: operating at over-capacity; factory breakdowns; and poor sanitation. More efficient operation of raw sugar factories would be possible with better knowledge of the governing principles of sugar extraction and crystallization.

OBJECTIVE: Increase yields in purer raw sugars.

RESEARCH APPROACHES:

A. Improve clarification efficiency and reduce losses during clarification and clarifier holdup.

B. Develop more rapid and efficient and less bulky clarifier-filtration processes; including the application of new innovations in ion-exchange, reverse osmosis, dialysis, chromatography, and other physical-chemical methods.

C. Develop a practical continuous crystallization (vacuum pan) system.

D. Develop improved sanitary practices including improved methods for cleaning and for reducing corrosion in evaporators and in other factory equipment.

E. Investigate the chemical-physical mechanisms of sucrose crystallization in model and natural systems, and the effects of different nonsugar constituents on crystallization rates and crystal characteristics in sucrose sirups and molasses.

## 406-C Higher Yields in Purer Refined Sugars

SITUATION: Refining raw sugar is increasingly expensive. Labor costs and technical difficulties are rising. The latter are attributable to poorer quality raws and to changes in the nature of the impurities. Also, present refining procedures do not always remove impurities even from high quality raws. In either case, additional expenses are incurred. Losses are also incurred when batches of refined sugars are rejected because of off-color or presence of other impurities, or because they cause "floc" in bottled beverages. The chemistry and physical-chemistry of the various refining processes are poorly understood. Moreover, the chemical nature of some of the impurities have not been sufficiently identified to suggest procedures for their elimination.

OBJECTIVE: To increase the yield and purity of refined cane sugar.

RESEARCH APPROACHES:

A. Identify chemically, and develop a practical method for the removal of colorants during the refining of raw sugars.

B. Evaluate new innovations in filtration, fractionation and coagulation for the removal of high ash forming impurities during refining.

C. Develop unit processes that are less costly in time, labor and equipment.

D. Investigate sucrose crystal formation in model and natural systems to obtain knowledge which may be used for the modification of sugar boiling practices to reduce the incorporation of impurities in the crystal structure.

E. Determine the chemistry and/or physical conditions responsible for floc and turbidity in bottled beverages in which refined sucrose is an ingredient.

406-D Direct Consumption Sugars for Food and Food Chemicals

SITUATION: Production of direct consumption (factory made white) sugars is declining in domestic factories. Louisiana raw sugar factories manufactured 40,000 tons of Turbinado sugar in 1958, and 250 tons in 1967. They manufactured 51,000 tons and 38,000 tons of granulated sugar respectively in these same two years. These two types of direct consumption sugars may be made by any one of a number of variations of carbonation and sulfitation processes. Reasons generally given for not making more of them are: high cost of manufacture, increasingly higher purity requirements, and competition of refined sugar products. They are used in chocolate coatings, caramel candies, bakery and dairy products, wine, feed formulations, and for curing tobacco. Potential markets for direct consumption sugars exist. Their expansion as well as the development of new markets depend upon the reduction of processing costs and finding new uses. Advantages in the manufacture of a direct consumption sugar are that remelting of the raw sugar and recrystallization are not required. Juice clarification costs, however, may be increased. New approaches are essential in developing an improved process which apply new advances in chemistry, physical-chemistry and chemical engineering.

OBJECTIVE: Reduce manufacturing costs and improve the purity of direct consumption sugars for food and food-chemical uses.

RESEARCH APPROACHES:

A. Reduce processing costs and increase purity by adaptations in present unit processes or the development of new ones.

B. Develop improved methods for reducing microbial contamination and for sterilization of the sugar.

C. Evaluate suitability of direct consumption sugars for use in more food products and for retail distribution.

D. Utilize as an organic chemical base for for manufacture of edible sucrose ester and sucrose ether products for application in the food industries.

# RPA 407 FEED AND NON-FOOD PRODUCTS

## 407-A New and Improved Feed and Industrial Products from Bagasse

SITUATION: Development of economic uses for bagasse is a major need in the sugarcane industry. Bagasse production in the United States and Puerto Rico, for example, for the 1967-68 grinding season is estimated at 4,000,000 tons (dry weight basis). Less than a fourth is used for manufacturing such products as paper, insulation board, chicken litter and mulch. The rest is burned, largely as a fuel in raw sugar factories despite a preference to burn other fuels where they are available and cheap. Industrial utilization of bagasse is occurring, but in countries where labor is less expensive than the United States. Furfural, plastics, alpha-cellulose, activated carbon, hardboard, and charcoal briquettes, are examples of additional products that may be made from bagasse. Major factors militating against its utilization other than for fuel are bulkiness, cost of transportation, and difficulty in storing. Notwithstanding these factors, continuing research is justified because of changes in economic conditions, advances in technology, and the need to make maximum use of agricultural materials.

OBJECTIVE: Provide the technology for the profitable utilization of bagasse by the development of improved processes and new products.

RESEARCH APPROACHES:

A. Develop better methods for the storage and transportation of bagasse.

B. Develop simple chemical, microbial or chemical-microbial processes for the conversion of bagasse into feed and food ingredients, particularly proteins.

C. Develop fundamental information on the chemical nature of the celluloses and lignins peculiar to bagasse.

D. Re-evaluate processes and products proposed in the past for utilization of bagasse in terms of present day needs, economics and technology.

## 407-B Increased Economic Returns from Molasses

SITUATION: Molasses is a by-product of sugar manufacture with a good potential for an improved economic return. It contains sucrose and other valuable constituents which could be recovered if new techniques were available. It should be possible to develop greater demand for molasses without the cost of additional processing. The uses for molasses are varied. The rum industry uses a significant amount. Yeast, citric acid, and pharmaceuticals are other examples. The material is increasingly being used for livestock feeds. These uses reflect the increasing recognition of the nutritional value of the product. Research is needed to derive full value from molasses. The non-uniform composition of the product is a problem. Total sugars may comprise 50 percent or more of its weight. The sucrose content ranges from 25 to 40 percent; reducing sugars from 12 to 35 percent. These and other variables have a marked effect on the problem of producing a uniform high quality rum. Technology is advancing in the use of cereal grains, thereby further increasing their competitive position. Molasses is a multi-use by-product with a good potential for new uses including the production of food and feed proteins. Intensive studies are needed to assure more complete and efficient use of the material.

OBJECTIVE: Increase the economic returns from molasses by developing techniques to extract valuable components, and improve procedures for manufacture of rum and other products.

RESEARCH APPROACHES:

A. Develop a simple inexpensive method for the recovery of sucrose from molasses.

B. Evaluate blackstrap molasses for food, feed, and pharmaceutical use by evaluating nutritional factors; developing techniques to remove off-flavors, toxicants, etc,; direct enrichment.

C. Develop processes for controlled utilization of molasses as a substrate by microorganisms for protein, alcohol, enzymes, antibiotics, and vitamins.

D. Determine rapid reliable analytic methods for molasses and rum compositions particularly suited for automatic in-plant control.

407-C Chemical Reactions of Sugar: Sucrose Chemicals as Non-Food Industrial Products.

SITUATION: The potential for industrial use of sugar and its byproducts is large. Sucrose may serve as an organic chemical base for the manufacture of surface coatings, plastics and plasticizers, agricultural chemicals, surfactants, fibers and films, solvents, explosives, adhesives, lubricants, and elastomers. The results of sucro-chemistry research are encouraging. This is partly because of the availability of additional chemicals at low cost, and the large and expanded market for chemicals, plastics, detergents, and protective coatings. New techniques are available to the chemist. More possibilities for reacting the sucrose molecule are visualized. Because sucrose can be produced in abundance economically, comprehensive, cooperative or otherwise coordinated research programs, should be initiated to assure its high value for use in the chemical industry.

OBJECTIVE: Transform sucrose into high-value industrial products for use in the chemical industry.

RESEARCH APPROACHES:

A. Prepare sucrose esters, using low-cost, fatty acid derivatives, and evaluate properties of products.

B. Prepare sucrose esters with varying degrees of substitutions and evaluate properties of products.

C. Synthesize organic acids and other chemical intermediates from sucrose and evaluate their properties.

D. Prepare polymers containing sucrose or derivatives and determine their properties.

E. Conduct pilot plant studies on products that appear to have industrial possibilities with the view to lower costs of production.

## 407-D Utilization of Muds, Condenser, and Cleaning Waters, and Other Factory Wastes

SITUATION: Utilization is a better term than disposal as we consider the disposition of factory muds, condensates, wash waters, and other wastes. A means must be found to derive benefits from these materials and eliminate their pollution effects. Mainland muds, for example, have up to 4 pounds of sugar for every ton of processed cane. There are waxes and organic and inorganic constituents. Muds have fertility and soil conditioning value. Condenser waters and leakages may carry thousands of pounds of sugar daily to the sewer lines. Impounding these fluid wastes alleviates the pollution problem for short-season operations, but eventually impounding develops its own problems. Air pollution from burning bagasse is also a problem in some areas.

OBJECTIVE: To develop simple, practical methods for utilizing sugar factory wastes to cover the cost of handling and reduce or eliminate pollution capabilities.

RESEARCH APPROACHES:

A. Study the problem of wax and fatty acids from filter press cake.

B. Evaluate the utilization of press cake in mulch, poultry feeds, mushroom composts, and as a source of nutrients in fermentations to produce industrial chemicals.

C. Develop practical automated methods for determining sucrose in waste waters.

D. Develop practical methods for flocculating and removing fine suspended matter from waste streams, particularly cane-cleaner wash water.

E. Evaluation of packed towers for biogradation of sugar factory wastes in lieu of conventional time and real estate lagooning.

F. Control of fermentation activity in impounding wastes.

G. Study the suitability of wastes for hydroponic farming or production of aquatic plants with value.

# RPA 408 MARKET QUALITY

## 408-A Quality of Sugarcane and Products During Marketing

SITUATION: The methods used to evaluate quality of sugarcane are unsatisfactory and outmoded. New methods that will accurately reflect variations in quality of individual farmer deliveries are needed to encourage producers to improve the quality of their crop. Simplified and reliable sampling schemes for bulk deliveries of sugarcane are needed. Research should be expanded to develop better methods for accurate, representative sampling of sugarcane and for more rapid, economical methods of sample preparation and analysis. The industry requires better tests to estimate sucrose in sugarcane. The present method for quality testing of cane molasses depends mainly on the Brix reading. The common practice of adding distiller's solubles upsets this method and may give an erroneous estimate of sugar content. Research should be initiated to determine the presence of such solubles as a part of the overall objective of improving the evaluation of molasses quality.

OBJECTIVE: Develop improved methods of sampling and testing sugarcane for sucrose, purity and fiber.

RESEARCH APPROACHES:

A. Develop techniques, instruments and procedures for sampling of sugarcane, including individual farmer deliveries and bulk deliveries.

B. Develop practical and objective methods of determining quality attributes of sugarcane and cane molasses including sucrose, purity and fiber.

# RPA 501 GRADES AND STANDARDS

## 501-A Improvement of Grades and Standards for Sugarcane

SITUATION: Grades and standards for sugarcane are essential for the division of proceeds among claimants, including the various growers of a factory area and the factory itself. Analytical procedures and standards of sugarcane quality are highly developed and extensively used, including the employment of these procedures and standards in the U.S. Sugar Act Program. Work in this field has been carried to such a high degree of development that no additional research effort on sugarcane grades and standards is needed.

The present level of research should be continued. In view of the changing technology and market conditions, such research is in the public interest. The research should be distributed according to the need and contribution of the total sugar supply.

## RPA 504 MARKET EFFICIENCY

### 504-A Physical and Economic Efficiency in Marketing

SITUATION: The rapid development of the food processing industry has brought about dramatic changes in the distribution of refined sugar. Today nearly seventy percent of the refined sugar distributed is shipped to food processors. A small number of sellers, operating in a highly competitive atmosphere, have through individual research tailored their marketing to the exacting and diversified requirements of the food processors, and the standardized grocery trade. The application of individual research to clearly defined consumer demands has led to a highly efficient marketing system.

No additional research effort is needed in sugarcane marketing. The present level should suffice to meet future needs. Additional research will be conducted by the industry as required.

# IV. SWEET SORGHUM GOALS AND PROBLEM AREAS

# RPA 208 CONTROL OF SWEET SORGHUM DISEASES

## 208-A Genetics and Breeding

SITUATION: Plant pathogens that infest sweet sorghum increase the hazards of production. Mosaic, leaf anthracnose, and rust are the most important diseases. Losses range from reduction in yields of stalks and sugar content to complete destruction of susceptible varieties. Downy mildew causes significant reductions in yields under some conditions. In some areas, chemicals used to control cotton insects cause serious damage to the crop. There is a need to breed for resistance to such chemicals. Genetic resistance has been identified for leaf anthracnose and rust, but not for all diseases.

OBJECTIVE: Determine the distribution and importance of plant pathogens, identify sources of resistance, and transfer this resistance to productive, well adapted varieties for sugar and sirup production.

RESEARCH APPROACHES:

A. Conduct surveys to identify and evaluate importance of pathogens.

B. Evaluate available germ plasm for resistance to diseases.

C. Determine inheritance of resistance.

D. Transfer resistance to productive, well adapted lines through breeding.

## RPA 307 BIOLOGICAL EFFICIENCY OF SWEET SORGHUM

### 307-A Management Practices

SITUATION: Sweet sorghum genotypes differ in response to photoperiods, temperatures, and other growth conditions. Crop sequence, land preparation, time of planting, fertilization, irrigation practices, time and method of harvesting, and postharvest conditions influence production of sugar and sirup from the crop. Growth conditions in sweet sorghum producing areas vary from humid to arid environments. It may be possible to develop strains adapted to each environment that are also tolerant to a range of growth conditions.

OBJECTIVE: Increase productivity per acre, improve quality for sugar and sirup production, and reduce the cost of producing a crop.

RESEARCH APPROACHES:

A. Evaluate cropping practices in relation to strain response.

B. Evaluate strains under various cultural and environmental conditions to determine characteristics associated with crop adaptability.

C. Evaluate plant characteristics to determine those that increase tolerance to extremes in temperature, photoperiod, and other growth conditions.

# RPA 406 NEW FOOD PRODUCTS FROM SWEET SORGHUM

## 406-A Sweet Sorghum as a Source of Sucrose

SITUATION: Sweet sorghum was recognized as a potential source of sucrose in 1870. Lack of an economic technology deterred adaptation of the crop for commercial production of sugar. Recent development of high sucrose varieties stimulated renewed commercial interest. Unlike sugarbeets and sugarcane, the newer high sucrose types of sweet sorghum contain relatively large quantities of starch. Conventional procedures to process sugarbeet and sugarcane juices rupture starch granules. The gelatinized starch produces high viscosities that interfere with sucrose recovery. Several years ago, a combined centrifugal-enzymatic sedimentation process was developed for removing impurities from sweet sorghum juice. It appears to be too expensive unless additional refinements can be made. Recent studies indicate a coagulation-sedimentation type process may be more efficient and less expensive. Both processes require refinements and further evaluation.

OBJECTIVE: Develop an economic process to recover sucrose from sweet sorghum juice.

RESEARCH APPROACHES:

A. Improve present processes or new techniques to clarify sweet sorghum juices and recover sucrose.

B. Identify major constituents and compositional changes affecting sugar recovery in relation to varieties, cultural practices, environment, time of harvest, and postharvest handling methods.

C. Adapt process for recovery of sugar from sweet sorghum to equipment currently used in sugarcane and sugarbeet factories.

# APPENDIX

## I. Sugar Act

The market for sugar in the United States, and in much of the world is highly regulated. After about 145 years of congressional actions affecting the sugar industry, the first Sugar Act was passed in 1934 known as the Jones-Costigan Act. It has been amended several times, but still carries the basic philosophy of the original act. It embodies three major objectives: (1) to assure adequate supplies of sugar to consumers at reasonable and stable prices; (2) to maintain a healthy domestic sugar industry and (3) to promote international trade.

The Act provides six principal means for dealing with the sugar problem. These are:

1. The determination each year of the quantity of sugar needed, at prices reasonable to consumers and fair to producers.

2. The division of the U. S. sugar market among the domestic and foreign supplying areas by the use of quotas.

3. The allotment of these quotas among the various processors in each domestic area.

4. The adjustment of production in each domestic area to the established quotas.

5. The levying of a tax on the processing of sugarcane and sugarbeets, with most of the proceeds to be used to make payments to producers to compensate them for adjusting their production to marketing quotas, and to augment their income.

6. The equitable division of sugar returns among beet and cane processors, growers, and farm workers.

In implementing the intent of the Sugar Act, the Secretary of Agriculture is required to determine, between October 1, and December 31, how much sugar will be needed by consumers in the continental United States during the next calendar year. He takes into consideration the amount of sugar used during the preceeding twelve months, the current sugar inventory, and prospective changes in population and demand conditions. Finally, he must estimate the next year's sugar price and index of prices paid by farmers in order to set a requirement figure that will not result in excessively high or low sugar prices.

The next step is dividing the required quantity among domesic and foreign producers. This allocation is made by statutory formula. The domestic quota is adjustable upward if the Secretary's estimate of requirements exceeds 10.4 million tons, and downward if requirements are less than 9.7 million tons. During the last few years the U. S. requirements in millions of tons has been as follows: 9.2 in 1965, 9.8 in 1966, 10.2 adjusted to 10.6 in 1967, and 10.4 announced in December 1967 for 1968. During 1968 a series of increases, beginning in May, raised the U. S. sugar requirements to 11 million tons. In December 1968 the requirements for 1969 of 10.6 million tons were announced. The allocation is roughly 3,000,000 tons to sugarbeet growers, and 1,000,000 tons each to (1) mainland sugarcane growers, (2) Hawaii, and (3) Puerto Rico. Some 4,000,000 tons would come from 31 foreign countries.

Quotas for the domestic sugar-producing areas are required by the Sugar Act. They are determined by the Secretary of Agriculture. Consumption estimates are the basis. For 1969, the estimate is 10.6 million tons. The quotas for each crop, given in percent, are as follows: 29.4 for sugarbeets, 10.7 for mainland cane, 11.3 for Hawaii, 10.8 for Puerto Rico, and 37.7 for foreign countries. Unused portions of domestic quotas are reallocated to foreign countries. The quotas carry out national policy to produce domestically about two-thirds of the U. S. requirement for sugar.

## II. Tables

### Table 1

Yield of Sugarcane, Sugarbeets, and Sugar Per Acre During Two Five-Year Periods

| Periods | Louisiana | Florida | Hawaii | Puerto Rico | Beet Area |
|---|---|---|---|---|---|
| | Average yield of cane or beets per harvested acre | | | | |
| 1958-62 | 22.2 | 35.9 | 87.4 | 30.4 | 17.2 |
| 1963-67 | 24.9 | 31.4 | 96.7 | 32.4 | 17.4 |
| % change | +12.2 | -12.5 | +10.6 | +6.6 | +1.2 |
| | Yield of sugar per harvested acre, short tons, raw value | | | | |
| 1958-62 | 1.96 | 3.60 | 9.47 | 3.15 | 2.44 |
| 1963-67 | 2.14 | 3.16 | 10.75 | 3.20 | 2.39 |
| % change | +9.2 | -12.2 | +13.5 | +1.6 | -2.0 |

### Table 2

Labor Requirements, Rates, and Costs Per Ton of Sugar During Two Five-Year Periods

| Periods | Louisiana | Florida | Hawaii | Puerto Rico | Beet Area |
|---|---|---|---|---|---|
| | Average man-hours per ton of sugar, raw value | | | | |
| 1958-62 | 42.0 | 23.1 | 15.9 | 87.1 | 21.6 |
| 1963-67 | 35.0 | 19.3 | 11.5 | 84.3 | 19.4 |
| % change | -16.7 | -16.5 | -27.7 | -3.2 | -10.2 |
| | Weighted average earnings per hour of field workers | | | | |
| 1958-62 | $ 0.76 | $ 1.05 | $ 2.41 | $ 0.53 | $ 1.11 |
| 1963-67 | 1.16 | 1.48 | 3.25 | 0.62 | 1.39 |
| % change | +52.6 | +41.0 | +34.9 | +17.0 | +25.2 |
| | Average labor costs per ton sugar, raw value, dollars | | | | |
| 1958-62 | 31.92 | 24.26 | 38.32 | 46.16 | 23.98 |
| 1963-67 | 40.60 | 28.56 | 37.38 | 52.27 | 26.97 |
| % change | +27.2 | +17.7 | -2.5 | +13.2 | +12.5 |